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ABILITIES PERTAINING TO CLASSES AND THE LEARNING OF CONCEPTS

Studies of Aptitudes of High-level Personnel

19

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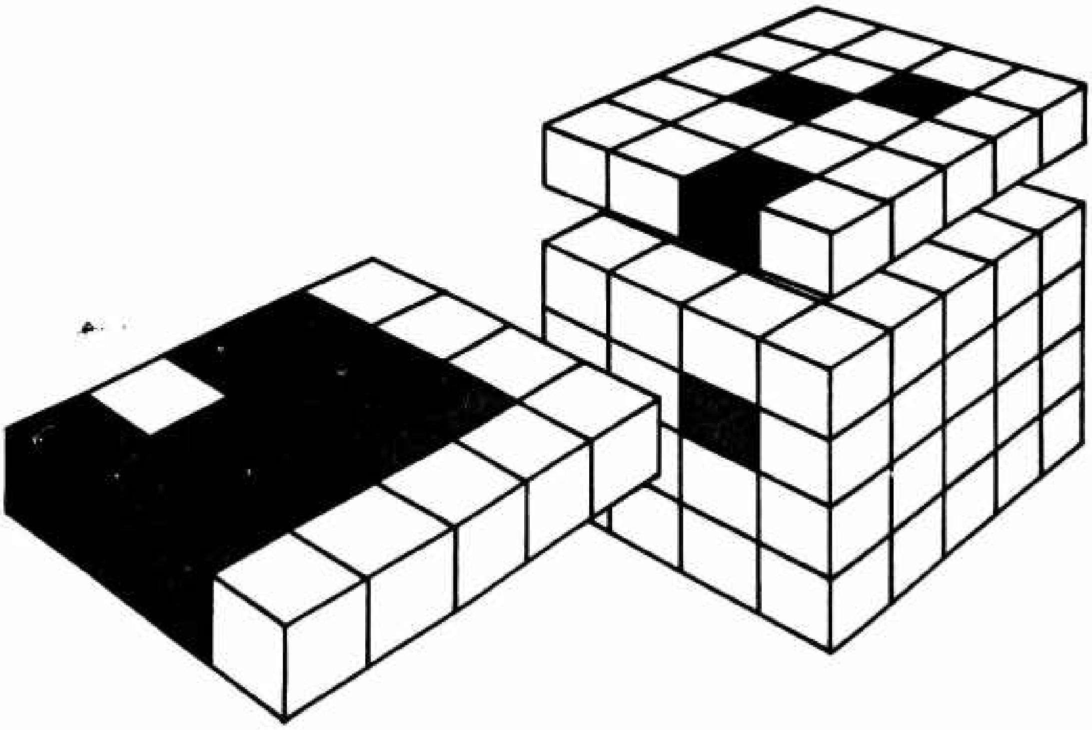

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ABILITIES PERTAINING TO CLASSES AND THE LEARNING OF CONCEPTS [1]

INTRODUCTION

This investigation had a double objective and a double problem. First, it sought to determine whether certain abilities involving class concepts represented in the structure-of-intellect theory and model (Guilford, 1959), but not yet revealed by factor analysis, could be demonstrated. This theoretical model calls for 20 such abilities, one for each of the five categories of operation within each of the four categories of content. Before this study was well under way, 12 of the abilities were believed to have been demonstrated by factor analysis, all of them by the Aptitudes Research Project. The study reported here sought to extend this list, to replicate the demonstration of 8 of the 12, to learn more about their properties, and to construct better tests for some of them.

The second major objective was to determine possible relationships between intellectual abilities and success in learning concepts. The acquiring of new concepts is of great importance in the processes of education. Much learning effort is devoted to the achieving of such goals. There has also been considerable interest in the problem of how new concepts come into being for an individual, as shown by psychologists in the experimental laboratory. The study of concept learning undertaken in this investigation represents a departure from traditional approaches, although not the first of its kind. It is the first time, however, that this approach has been based upon any comprehensive theory of intellectual abilities. It applies the conceptual basis provided by the structure-of-intellect (SI) theory.

THEORETICAL BACKGROUND

The theoretical background presented here will refer to the sources from which information concerning the known classes abilities has come, to studies of concept learning that approach the problem by means of similar multivariate techniques, and to logical reasons for expecting that classes abilities, and others, should be relevant to the learning process.

The Known Abilities for Dealing with Classes

To facilitate discussions of the classes abilities here and later, Table 1 is provided. It extracts from the total structure-of-intellect model the horizontal

Table I

A Matrix of Abilities Pertaining to Classes, with Variations of Content and Operation

	Figural	Symbolic	Semantic	Behavioral
Cognition	CFC K, I	CSC K, I	CMC K, I	CBC K
Memory	MFC U	MSC K, I	MMC K, I	MBC U
Divergent Production	DFC K, I	DSC K, I	DMC K, I	DBC U
Convergent Production	NFC U, I	NSC U, I	NMC K, I	NBC U
Evaluation	EFC U	ESC K	EMC K	EBC U

K - known or previously demonstrated.

U - unknown or not previously demonstrated

I - under investigation in this study.

[1] This study is one of a series conducted by the Aptitudes Research Project at the University of Southern California, under Contract Nonr-228(20) with the Office of Naval Research, Personnel and Training Branch. The ideas expressed here are our own and do not necessarily reflect the views of that agency. This material may be reproduced for any purpose of the United States Government. Among the authors, Guilford was Responsible Investigator and Director of the Project, Hoepfner was Assistant Director and Dunham was the Study Leader.

layer containing the abilities pertaining to classes, and it contains 20 cells, to represent the 20 classes abilities mentioned earlier. Each cell has its unique trigram symbol, for its particular conjunction of operation, content, and product.

In order to tie the known classes factors with their sources, the pertinent references are cited in connection with each one:

CFC (Guilford, et al., 1954; Kettner, et al., 1959; Gershon, et al., 1963)

CSC (Kettner, et al., 1959; Guilford, et al., 1960; Hoepfner, et al., 1965)

CMC (Hertzka, et al., 1954; Kettner, et al., 1959; Merrifield, et al., 1962; Nihira, et al., 1964)

CBC (O'Sullivan, et al., 1965)

MSC (Tenopyr, et al., 1966)

MMC (Brown, et al., 1966)

DFC (Gershon, et al., 1963)

DSC (Gershon, et al., 1963)

DMC (Wilson, et al., 1954; Frick, et al., 1959; Guilford, et al., 1961; Merrifield, et al., 1963)

NMC (Merrifield, et al., 1962)

ESC (Hoepfner, et al., 1964)

EMC (Nihira et al., 1964)

From this list of the previous reports that demonstrated classes factors, it would seem that the seven that had been demonstrated only once should be the most likely condidates for replicative study. But, as stated earlier, there were other considerations regarding the potential relevance of various classes factors in connection with concept learning.

Of the classes factors, it was thought that the cognition abilities should be most relevant. They are among the classes abilities most investigated earlier. The memory-for-classes abilities seemed to be likely candidates for relevance, because the concept-learning tasks, presenting one exemplar of a class concept after another, required the subject (S) to remember previous exemplars and their common features. S should also be helped in learning concepts by being able to recall previously learned class ideas, which suggests the relevance of both divergent and convergent production of classes. Evaluative abilities dealing with classes seemed least likely to enter materially into the performances on the concept-learning tasks, so none was included. None of the learning tasks involved behavioral information, so the behavioral category of abilities was not represented in this study.

It would have been desirable to have included tests for all 20 of the abilities represented in Table 1, in satisfaction of both major objectives of the investigation, but a factor-analytic study must inevitably be restricted with respect to the number of factors investigated because of limitations of testing time. Also to be considered is the need to include some reference factors and their tests not under special investigation, in this case, some abilities not dealing with classes. Hence a number of compromises had to be tolerated.

Possible Roles of Ability Factors in Learning

T. S. Kendler (1961) one time divided the theorists of concept learning into categories. One type of theory is concerned primarily with the stimulus and its response, and treats concept learning as an extension of discrimination learning (e.g., Bourne and Restle, 1959). The other type focuses on the processes intervening between stimulus and response. The theorists concerned with intervening processes seem to be of two types: (1) the neo-behaviorists who postulate internalized S-R bonds, which mediate between the stimulus and the response (e.g., H. H. Kendler and D'Amato, 1955), and (2) the cognitive theorists who are concerned with the hypothesis-testing strategies employed by S (e.g., Bruner et al., 1956). Even the cognitive concept-learning theorists have ignored the possibility that processes relevant to the learning of a concept can, in part, be identified with known abilities that have been measured and investigated in psychometric laboratories for some time.

The present authors believe the latter type of theorist to be the more promising, however. In complex learning situations such as a concept-learning task, S does not sit passively, learning only at the whim of the experimenter's manipulation of conditions such as frequency of reinforcement, interval of reinforcement, number of relevant dimensions, and so on. Granted that these are important variables affecting the learning process, they do not tell the whole story. S recognizes attributes common to the stimuli, he produces and tests hypotheses concerning which attributes are relevant, and he remembers what occurred on previous trials. The last statement implies all five of the operations of the SI model. The potential for the understanding of concept learning is in the investigation of these processes that S performs between receiving of the stimulus and the production of the overt response.

At least one theorist (Ferguson, 1954, 1956) has recognized the value of abilities for learning theory. Ferguson assumes that abilities ".... are attributes of behavior, which through learning have attained a crude stability or invariance in the adult." (Ferguson, 1956, p. 121). He asserts that by means of transfer, abilities exert their effects differentially in learning situations. Thus, abilities revealed by factor analysis can be regarded as somewhat generalized skills that have pertinent uses or transfer functions, each where a task belongs to the family of tasks to which the skill applies, such as the tests for that factor. Because the behavior of the learner, including his strategy and his tactic, changes during the course of learning, abilities that transfer and produce effects at one stage of learning may differ from those effective at other stages.

Apparently the first to suggest that factorial abilities should be involved in learning and the first to investigate the general problem was Woodrow (1938, 1939a;b). Using tests of intellectual abilities, Woodrow demonstrated that with practice in performing on tests, those tests changed in factor composition, and that loadings on a verbal factor tended to decline with continued practice on a number of tests. Woodrow (1939c) also demonstrated mathematically that any factors contributing to variances in a gain score (later-trial score minus an earlier-trial score) must be shared with the terminal scores from which the gain score is derived. Since learning is concerned with changes in scores, this means that factor analysis of trial scores can tell us what abilities are relevant with respect to gains. Subsequent investigations have analyzed trial scores from different stages of practice in a learning event.

Role of Factor Abilities in Psychomotor Learning

Most of the information of this kind has come from Fleishman and his coworkers. First, Fleishman and Hempel (1954, 1955) analyzed successive scores obtained from learning sessions with the Complex Coordination test and the Discrimination Reaction Time test along with marker tests that measure factors previously known to be common to the initial performance scores and other factors that were thought to have some relevance later in the two learning events. They found abundant evidence that for certain cognitive abilities the factor loadings tended to decrease systematically with practice and that for certain psychomotor abilities loadings tended to increase. For some other factors there were instances of fairly stable degrees of involvement throughout practice. A factor common to the trial scores only, increased systematically in importance with practice.

The changes in relative importance of cognition versus motor abilities suggests that first trials demand more cognitive control of movements, but as the task becomes better structured cognitively, psychomotor abilities become more important in the performance of the task. Limits in those abilities determine to a greater extent the individual differences in skilled performance. But another analysis by Fleishman and Rich (1963), using a Two-Hand Coordination task, showed that a kinesthetic-sensitivity ability (as measured by a lifted-weights test) also tended to increase in importance in the later trials. Together with other findings, this result suggests that with practice there is a shifting from visual to kinesthetic control of movements.

In a learning experiment with a task without psychomotor involvement, Fleishman and Fruchter (1960) investigated factors involved in mastering the receiving of Morse-code signals. Two abilities that had relatively strong relations with scores early in practice, with decreasing importance later, can be identified with two auditory factors in the SI model — cognition of auditory-figural units and cognition of auditory-figural systems. One should expect such abilities to be involved.[2]

[2] The reports of the Fleishman experiments have been summarized in somewhat greater detail by Guilford (1967).

Factorial Studies of Other Types of Learning Tasks

A number of factorial investigations involving learning of a more intellectual character, including concept learning, have been conducted at Princeton University. Stake (1961) investigated the relationships of rote-and relational-learning tasks with academic achievement and various mental abilities. Learning curves were fitted to the learning scores, and parameters were determined for each person for each task. Parameter values were then factor analyzed together with the ability and achievement scores. Twelve factors were identified, eight of which were restricted to the learning tasks. The results indicated that learning is related to the ability and achievement measures, but there are also contributing determiners independent of these measures.

Allison (1960) administered 13 learning tasks hypothesized to represent three types of learning—rote, conceptual, and motor learning. He derived parameters from fitted learning curves and investigated their relationships with ability and achievement measures. He interpreted seven learning factors and five ability factors, four of which were in common to the two domains. The three learning factors that were independent of the ability measures were interpreted as rote learning, spatial rote learning, and early-versus-late learning. Again, there is evidence that learning is partially related to abilities, and that there are learning factors that are independent of ability measures but that are in common to some learning tasks.

Duncanson (1964) administered a battery of ability tests in conjunction with three types of learning tasks—concept formation, paired associates, and rote learning. Each type included one task with verbal, one with numerical, and one with figural material. He employed a procedure developed by Tucker (1958, 1960), which permits the decomposition of the learning records of a number of people on a single learning task into component curves and the determination of the contribution of each curve to each person's learning performance. Each learning task was subjected to a separate factor analysis in order to determine the number of factors necessary to describe the learning performances of the subjects on that particular task. Factor scores were then calculated for the subjects, and the factor scores of all the subjects on all the tasks were entered into a factor analysis together with the scores on the ability measures.

Seven factors were extracted and rotations were made to an equamax solution. One factor was found to be restricted to the ability measures. It was interpreted as a speed factor. Three factors were common to the ability and learning measures. They were interpreted as verbal ability, rote-memory ability, and reasoning ability. Three factors were restricted to the learning measures. They were interpreted as verbal learning, nonverbal learning, and concept formation.

Prior to the use of factor analysis in the study of relations between learning scores and ability-test scores, correlations between the two kinds of measures were found to be low, indicating little relationship. The correlations were low in part because of the low reliabilities of scores, as Duncanson (1964) has pointed out. Tilton (1949) had criticized many of the early non-factorial studies on the basis of the unusually low reliabilities of learning scores. Fortunately, factor analysis can still be a powerful tool in studies of this kind in that it permits the discovery of common-factor variances even when reliabilities are low. One should not expect high factor loadings, but this raises the problem of whether factor loadings are statistically significantly different from zero. The latter problem has not been solved for the case in which principal-axes extractions and rotations of axes have been employed.

In spite of these reservations, it is now apparent that mental abilities do contribute to performance in many learning situations. From the Princeton studies just cited and others to be mentioned shortly, it is not clear just what the relations between factors and learning scores are. The experiments were designed without regard to any general theory of mental abilities, and the factors are difficult to interpret in line with other known factors, owing not only to less than optimal selection of ability variables but also to the application of "blind" analytical methods of rotation that leave much to be desired when it comes to interpretation of the factors. Factors said to be restricted to learning scores are of unknown status. It is possible that they simply represent composites of abilities not differentially sampled by the tests of abilities. Had marker tests for additional common factors been in the analyzed battery, some of these "specific" learning factors might have been accounted for.

Apart from the Princeton scene, Games (1962) investigated the learning of a number of verbal tasks, in both paired-associates and serial-learning form. The tasks were varied with respect to method of presentation (anticipation and recall), type of response (oral and written), and order of presentation. He factor analyzed the scores on six marker tests designed to measure the factors of rote memory and span memory, after which he projected trial scores from the learning tasks into the reference frame of the factors determined by the ability tests alone. As in the Fleishman and Fruchter study (1960), the learning scores were not permitted to help to establish the factor structure. In this way, no within-task factor or factors can be found, and such factors would have no chance to confuse the common-factor picture. Games found that the learning performances were related to the memory factors (much more to the rote-memory factor than to the span-memory factor). But with respect to variations in method of testing retention, type of motor response, and order of presentation, the results were inconclusive.

Factorial Studies of Concept Learning

One of the learning tasks in the Stake (1961) investigation falls in the category of concept learning, for it required the sorting of cards into four categories, white things, household things, common edibles, and living things. Scores from this task had no appreciable loadings on any common factor and did not enter into the interpretation of any factor. It had the lowest communality of all the 12 learning tasks that he used, indicating that if any intellectual abilities were involved they were not represented in his test battery. This sorting task was very different from all the tests in the battery and from the other learning tasks.

Duncanson (1964) used three concept-formation tasks that were of essentially the same type except for differences in kind of material—verbal, numerical, and figural. Each task consisted of a series of stimulus displays, each an instance of the concept or not an instance. S was to decide whether or not a display was an instance of the concept, and he was then informed as to the correctness of his choice. The three concept-formation tasks were loaded on one factor and on no others, and no other variables were loaded on that factor.

Allison (1960) included four concept-formation tasks in his learning battery. All involved assigning one of four letters as a label to sets of four words or sets of four figures. Two of the tasks involved verbal information and two figural information. S was shown a set, he assigned one of the four letter labels, and he was immediately informed which letter was correct. In the analysis, the concept-learning tasks loaded predominantly on one factor, which was interpreted as conceptual learning. Through an inter-battery factor analysis it was found that this factor was related to most of the reference aptitude factors, a finding contrary to the findings of Stake (1961) and Duncanson (1964). It may be significant that Allison's marker tests were different from those of Stake and Duncanson.

Recently two investigators (Bunderson, 1965, and Manley, 1965) have concentrated soley on the relationship between concept learning and abilities. Bunderson administered 30 marker tests and 26 concept-attainment problems to 145 university undergraduates. His concept-learning task involved eight stimuli containing eight geometric-type figures. A concept to be learned might be "black triangle." In each trial, S was shown a card, to say whether or not it was an exemplar of the concept. Learning scores were obtained by combining sets of successive trials.

The marker tests were factor analyzed in order to determine their common-factor structure and the learning scores were located within that structure. Ten mental-ability factors were interpreted after equamax rotations: three reasoning abilities, two flexibility factors, three memory abilities, and two visual-speed factors. Bunderson found relations between his concept-task scores and the three reasoning abilities and the visual-speed factors. Bunderson postulated three higher-order processes: problem analysis, search, and organization. The lower order factors appeared loaded differentially at different stages of practice, supporting his postulation of the higher-order processes. The naming of the higher-order processes is suggestive of stages in problem solving. In a real sense, the S involved in a concept-attainment task is solving a problem. It has sometimes been noted (e.g., Merrifield, et al., 1962) that intellectual abilities play roles in solving problems, the relevance of each factor depending upon the nature of the problem.

Manley (1965) administered a battery of mental-ability tests, representing seven previously identified factors, to 119 male ninth-grade students. The seven reference factors were: flexibility of closure, induction, associative memory, number facility, general reasoning, syllogistic reasoning, and verbal comprehension. Incidentally, three of these factors are identifiable with SI abilities, but as for the other four, each probably comprised two SI abilities. In the factor analysis, seven factors appeared, but two were uninterpreted and the other five seem to be even more complex in terms of SI analogs that the original seven hypothesized factor concepts with which the study began. Like the other studies of concept learning mentioned here, this one included no marker tests for classes factors. Tests marking classes factors, at least those for cognition of classes, would seem to be the most natural ones to include. It cannot be claimed that classes tests are too much like concept-learning tasks to be tolerated as being sufficiently different. None of the classes tests used in the present investigation can be said to be alternate forms of the concept-learning tasks. Any resemblance that does occur should be a rational basis for hypothesizing the relevance of the tests' factors for the process of concept development.

Manley's concept-learning tasks were of three types: involving nonverbal concepts restricted by the attributes of the stimuli, nonverbal concepts without such restrictions, and verbal concepts. There were four learning problems of each type. An error score was obtained from each of the 12 tasks to use in the factor analysis. The tests and the learning scores were analyzed together. The results showed three learning-task factors, one for each type of task. The learning scores had little or no relation to the factors determined by the ability tests. Had there been any marker classes tests in the battery, and had the task-score variables not been analyzed along with the test scores but merely extended into the factor structure, the results might have been very different, assuming, also, better rotation.

HYPOTHESES, TESTS, AND LEARNING TASKS

The Classes Factors and Their Tests

As in most recent studies by the Aptitudes Research Project, the nature of the factors to be expected is inferred from their places in the structure-of-intellect model. The properties of each ability are specified by its conjunction of values on the three parameters—operation, content, and product. For parallel factors there should be parallel tests. Such parallels will be pointed out as the pertinent features of the tests are described. All tests, whether designed for classes or not, are listed alphabetically with some technical items of information and sample items, in Appendix A. Here we are concerned with general principles.

Tests for Cognition of Classes

Cognition means simply awareness or comprehension of information. Test items that indicate whether or not examinees have possession of certain class ideas or class concepts are sufficient to tell us about their characteristic levels on scales of cognition-of-classes abilities. Prior to this investigation, certain types of tests had been used and found to be discriminative among individuals along the cognition-of-classes dimensions. Not all types had been used with all kinds of information (content).

Commonly used for cognition have been tests of the "exclusion" type, in which four or five potential exemplars of a class concept are given in each item, one of which does not belong to the class and the examinee (E) is to identify it. Three such tests were used in this investigation, although they were known not to be among the most successful tests in previous analyses. They had correlated lower with other tests of their same factors than is usual. The reason was revealed by the results in this analysis. The three exclusion tests were Figure Exclusion, Letter-Group Exclusion, and Word Grouping, for factors CFC, CSC, and CMC, respectively.

Another variety of cognition-of-classes test may be called an "inclusion" test, for it asks what single unit of information belongs in a class that is to be identified by E from a set of two or three exemplars. The single unit is to be selected from five alternatives. The inclusion tests used in the present analysis were Figure Class Inclusion and Letter Classification, for the factors of CFC and CSC, respectively.

A third kind of test in this special area is in matching format. Four sets of exemplars, each set forming a class the concept of which is to be cognized, are presented along with five alternative potential exemplars. Figure Classification, Number Classification, and Verbal Classification may be grouped in this category, for factors CFC, CSC, and CMC, respectively. Verbal Classification differs from the others by having only two classes, each represented by four exemplars, with eight words to be put in one class or the other, or in neither. The restriction to two classes and the addition of the "neither" alternative might be expected to involve some complications, and we shall see that this is so.

A fourth kind of test was used in connection with factor CSC only. Number-Group Naming presents a set of three numbers in each item, with E to name the concept or otherwise to verbalize it. Such tests in the other content categories have been found typically loaded on factor NMU, originally called a "naming" factor but later recognized as the convergent production of semantic units (NMU), in the SI model. Evidently the difficulty of naming the class concepts in such tests is ordinarily more difficult and is a heavier contributor to variances in scores than is the step of cognizing the class concept, hence the significant loading on NMU. Apparently in the case of Number-Group Naming the reverse is true, for it has a history of loading on the CSC factor.

Tests for the Memory of Classes

The four tests for the memory-for-classes abilities, two for each factor, were in the category of marker tests, since those two factors were not under special investigation. Two principles are represented in these four tests. In three of them, E studies sets of three exemplars on the study page, in each of which some particular class concept should be readily cogized, so easily that there should be no cognition variance in the test scores. The retention test that follows, usually immediately, offers for recognition, not the same exemplars but the same class concept represented by the new exemplars. The replicated classes are of course mixed with negative instances of similar classes.

Memory for Nonsense Word Classes presents for study sets of trigrams, such as GID, VID, JID, with the correct set for recognition such as ZID, FID, NID. Memory for Word Classes is much the same, using familiar words instead of meaningless trigrams, the class concepts being dependent upon spelling features, hence both tests were markers for factor MSC. Classified Information is in similar format, but the classes depend upon common meanings of the words, hence it represents factor MMC. A set that was studied might contain: SILK WOOL NYLON, and the set to be recognized might be: RAYON COTTON FELT.

The other marker test for MMC was Picture Class Memory, in which the studied sets are made up of three pictured familiar objects, such as articles of clothing used for keeping warm in cold weather. The set given for recognition contains pictures of such clothing with two exemplars. One of these exemplars is identical with one in the studied set, given along with a new one that represents the class well. A mislead alternative response presents another exemplar from the same studied class, but it is paired with an exemplar representing some other class.

Tests for Divergent Production of Classes

Divergent production rests upon the recall of information from memory storage to satisfy certain needs raised by test items. The test items are "open" in the sense that many different responses are relevant and more or less appropriate. The scoring of such tests emphasizes quantity of production and variety. Three general principles are represented in the nine tests used for factors DFC, DSC, and DMC, some of the tests being newly constructed.

The production of classes means the construction of groups, putting exemplars appropriately into those groups. This holds true for either divergent or convergent production. The difference between the two operation categories is that divergent classification involves multiple ways of grouping items of information, whereas convergent classification is hedged-in with sufficient restrictions so that only one class will do. In divergent classification, the same item of information appears in more than one class; in convergent classification, an item of information is an exemplar of only one class concpet, unless the rules specify other conditions, still restrictive.

A regrouping acitivity of some kind is a natural one for a test of divergent production of classes, a principle that is applied in two ways. One way is to present a limited list of units, each of which has several attributes, each of which is held in common by some other unit in the list. For example, Alternate Letter Groups gives eight capital letters from the alphabet, with E to group and regroup them in as many ways as he can. Common attributes are: all straight lines, all curved lines, a combination of curves and straight lines, closed figures, figures containing parallel lines, and so on. Although letters are used, note that it is the figural properties that provide the basis for classification, hence this test is for DFC, not DSC. Another DFC test, Multiple Grouping of Figures, provides nine figures each containing some geometric attributes.

Two tests for factor DSC also employ the same regrouping principle. Multiple Grouping of Nonsense Words provides a list of 10 letter groups. Name Grouping presents lists, each of nine given names, to be grouped and regrouped in terms of certain letter or letter-combination properties. One semantic test for DMC (Multiple Grouping), follows the regrouping principle by giving a list of seven well-known words to be regrouped in terms of the meanings they entail.

A second regrouping type of test has the variation of giving one set of three units that has a number of common attributes that make it a candidate for grouping with different units selected from a list. Multiple Figural Similarities presents a set of three figures and a list of ten other figures, with E to find a number of such units that can be classed with the set, each for a different reason. A parallel test for factor DSC, Multiple Letter Similarities, gives a set of three letter groups and a list of other letter groups, with E to select one group in turn to classify with the given letter-group set.

For factor DMC, a quite different principle has been applied, a principle that has a bit of historical interest. When DMC was first revealed (Wilson, et al., 1954), it was interpreted as "spontaneous flexibility." It was strongly loaded on the "shift" score from the test Brick Uses, which calls for listing as many different uses for a common brick as E can produce in limited time. The shift score is a count of the number of times E changes category of uses, e.g., going from a brick as building material to uses as a missile, a weight, a marker, and so on. It was later recognized that what E is doing in order to earn a good score is to reclassify a brick. It was subsequently found that a multiple-grouping test, which more obviously satisfies the SI specifications for DMC, helps to define the same factor (Guilford et al., 1961; Hoepfner and Guilford, 1965). In the current analysis, two tests for DMC are based upon the shift principle. The Utility Test includes the activities of listing uses for a brick and for a common wooden lead pencil. Alternate Uses asks for listing of unusual uses of a number of familiar objects, the ordinary use being excluded. This condition almost automatically entails changes of category with every response. Every use is a function of some different attribute of the object.

Tests of Convergent Production of Classes

As stated earlier, in the convergent production of classes, restrictions ordinarily preclude more than one right answer. The tests can be similar to those for divergent production of classes with some added features of restriction. Restrictions can be of various kinds, but the full range of those kinds is not known.

The simplest principle is that of presenting a list of n units that are to be classified into mutually exclusive groups. A test following this principle calls for the act of partitioning a collection of items of information. Such a test was the first to reveal a factor that could be interpreted as NMC (Merrifield, et al., 1962). The test, Word Grouping, presented a list of 12 very familiar words, with E to form four classes, no word to be in more than one class and every word being classified. In the current study, in which factors NFC and NSC were being investigated for the first time, completely parallel tests were developed in the form of Figure Grouping for NFC and Letter Grouping for NSC, the units in the latter instance being trigrams.

A modification of the partitioning type of test just described presents a list of nine units—nine figures, letter groups, or words—to be grouped by threes, so that a given single "target" unit, or model, can belong to each of the three classes in turn. For example, a lone square can be grouped with three quadrilaterals, with three figures containing parallel lines, and with three figures containing right angles, as in the test Figure-Concept Grouping. Letter-Concept Grouping and Concept Grouping are similar tests for NSC and NMC, respectively.

Another modification of the partitioning type is seen in Group Classification, for NMC. Each potential exemplar is composed of a set of four words, one of which is the "attribute" in common to words of similar meaning in other sets of four. Eight such sets are given, with two additional target sets to serve as models for the two classes that are to be formed from the eight.

Another controlled-grouping test permitted using each unit two times (and only two). Given a list of six units of one kind of content, E is to form two sets of two classes each. This is true of Restricted Figural Classification, for NFC, and for Restricted Symbolic Classification, for NSC. No corresponding test form was used for NMC.

One test of the partitioning type presents nine words, with E to separate them into two classes so that one of the classes should be as large as possible. Largest Class, for NMC, is of this type.

Finally, as an attempt to design a quite different type of test and with some desire to test the degree of generality of factor NFC, the test Figural Hierarchical Grouping was designed. Given a list of either 7 or 15 complex figures in an item of this test, E is to find the most general case, two major classes under it, and two minor classes under each of the major classes, when 7 figures are presented, and two subclasses under each of the minor classes, in addition, when 15 figures are given. Such a complex test might well be expected to load on more than one factor, and the results did show a substantial loading on another factor.

The Reference Factors and Their Tests.

Tests of four reference factors outside the category of classes abilities were included in the analysis, with the expectation that they would possibly contribute significantly to variances in scores from the classes tests. A completely adequate set of reference factors was impossible to include because of the limitation of available testing time. The reference factors and their marker tests were:

CMU - cognition of semantic units

- Verbal Comprehension (a multiple-choice vocabulary test)
- Word Completion (a completion or defining type of vocabulary test).

CMS - cognition of semantic systems

- Problem Solving (an arithmetical-reasoning test)
- Ship Destination Test

DSU - divergent production of symbolic units

- Suffixes
- Word Fluency

NMU - convergent production of semantic units

- Naming Meaningful Trends (formerly Seeing Trends)
- Picture-Group Naming
- Word-Group Naming

It will be noted that the last two titles suggest that they refer to classes tests, and that had been the original intention in their construction, but experience has shown that they are strongly related to factor NMU instead. In this study there was another opportunity to see whether they have any classes variance. No tests had been especially designed for NMU when this investigation was conducted. Such tests will probably involve neither relations (as in trends tests) nor classes.

The Tasks Used in Concept Learning

There were three concept-learning tasks, one for each kind of content—figural, symbolic, and semantic. In each task, the subject (S) was to learn four different concepts, labeled A, B, C, and D. [3] In each learning trial, S was presented with an exemplar of one of the four concepts and he was to indicate which concept it represented by encircling one of the four letter labels (see Appendix B for copies of the instructions and for two successive sample pages from the task booklet). The presentations were orgainzed in the form of a teaching book, so that each page (after

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[3] Following the custom in these Reports, when an examinee takes tests he is designated by E. Following general custom, S is a subject in an experiment. In this study the same individuals served in both capacities.

the first) presented again the exemplar of the preceding page along with the right letter response, thus giving S immediate feedback information. S was told to guess when he thought he did not know the answer.

The figural task involved geometric types of figures. The four concepts to be learned were in the nature of figures containing: (A) intersecting lines, (B) a right angle, (C) a dotted line, and (D) parallel lines, respectively. The symbolic task presented in each trial a four-letter nonsense word. The four concepts involved words with: (A) a repeated letter, (B) the letter S, (C) an initial vowel, and (D) the first three letters in alphabetical order. Each stimulus in the semantic task was composed of a set of four English words, one of which belonged to the class. The four classes were composed of: (A) leaders, (B) edible things, (C) animal sounds, and (D) parts of wholes.

In each task there were 96 trials, each of the four concepts being represented by different exemplars a total of 24 times, with the concepts appearing in random sequence. In group presentation of the tasks, the experimenter paced the subjects by telling them to turn a page every five seconds. Proctors were present to catch possible deviations.

PROCEDURES AND DATA PROCESSING

Test and Task Operations[4]

Test Development

Sixteen new tests were constructed, employing the SI model in two ways. First, specific examples of tasks were deduced from the operation-content-product combinations. Second, tasks were devised by analogy to those that had proved to be successful for parallel SI abilities, those having one or two categorical attributes in common. Thus, a test for factor NSC could be written similar to a test for NMC, the only difference being the kind of content, or similar to one for DSC, the only difference being the kind of operation. Many examples of such parallels can be seen in the discussion of classes tests earlier. Twenty-seven tests were selected from the list of recommended tests for identified SI factors provided by Guilford and Hoepfner (1963). New items were written for three of these tests—Figure Classification, Figure Exclusion, and Word Classification, with attempts to increase reliability and univocality. The names of three tests were changed in order to make their labels more indicative of the abilities they measure. Sentence Evaluation was changed to Sentence Classification; Letter Grouping to Letter-Group Exclusion; and Seeing Trends I to Naming Meaningful Trends.

The new and revised tests were pretested to determine clarity of instructions, appropriate difficulty levels, test reliabilities, and optimal time requirements. In this process, the tests were administered to samples of junior-college and university students.[5]

Subjects

The subjects for the main experiment were 271 male and female, junior and senior students, at a high school in a middle-class urban area in Southern California.[6] Unfortunately, at the time of administration of tests and concept-learning tasks, an influenza epidemic was rampant and attritionwas unusually high. Eliminating subjects whe were lacking scores on any tests or tasks decreased the number to 177.

Administration of Tests and Tasks

Administration of tests and tasks took place in a large auditorium. The total time required was nine hours, divided into three sessions of three hours each, on different days. The juniors were tested during one week and the seniors the following week.

The tests were presented in nine printed booklets, with the restriction that two tests for the same factor should not appear in the same booklet. The symbolic task was given the first day, the figural task on the second, and the semantic task on the third.

Scoring

All tests were scored by hand and independently check-scored by a different scorer. Scoring formulas were applied to multiple-choice tests to correct for guessing. Statements regarding the nature of the score and the scoring formula used for each test appear in Appendix A, included in the general description of the test.

Each S's responses from the learning tasks were punched onto IBM cards. Three kinds of scores were used. One score was designed to show how well each S was doing on a task at different stages of learning, and two other scores were to show how much S had learned about the four concepts in the task as a whole, and how rapidly he had learned.

For the "stage" scores, the 96 trials weregrouped into 12 stages of eight trials each. The number of correct responses given in any stage was S's score for that stage. All four concepts of one kind of content were invloved in this kind of score. From such scores, learning curves could be derived, and the factor composition could be estimated for each stage.

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[4] Special thanks are due Miss Kaaren Ingebretsen, Mr. William Doherty, and Miss Sandi Alexander, who assisted respectively, in the test-construction, data-analysis, and scoring stages of this study.

[5] For this pretesting we are indebted to Dr. Henry Slucki of the University of Southern California and to Mr. Hugh M. Petersen of Pasadena City College.

[6] For this testing we are very much indebted to Mr. George Prince, Assistant Principle, Mr. Herbert Abrams, Counselor, and Mrs. Marie Sander, Coordinator of Guidance, of Mayfair High School, Lakewood, California and to Dr. Gertrude Wood, Coordinator of Programs for Gifted Children & Youth, Office of the Los Angeles County Superintendent of Schools.

Table 2

Means, Standard Deviations, and Reliabilities of Test Scores

	Test Name and Code	Mean	Standard Deviation	Reliability
1.	Alternate Letter Groups DFC03B	17.12	3.76	.71
2.	Alternate Uses DMC03C	12.92	5.37	.81
3.	Classified Information MMC01A	42.50	14.27	.78
4.	Concept Grouping NMC02A	15.46	3.35	.70
5.	Figural Class Inclusion CFC04A	11.29	5.17	.69
6.	Figural Hierarchical Grouping NFC02A	6.93	5.07	.75
7.	Figure Classification CFC01A	9.95	4.03	.61
8.	Figure-Concept Grouping NFC03A	12.23	3.79	.72
9.	Figure Exclusion CFC03A	15.10	4.30	.46
10.	Figure Grouping NFC01A	52.72	13.61	.80
11.	Group Classification NMC03A	16.27	7.29	.32
12.	Largest Class NMC04A	3.07	1.76	.54
13.	Letter Classification CSC06A	11.66	4.73	.75
14.	Letter-Concept Grouping NSC02A	8.62	4.77	.82
15.	Letter-Group Exclusion CSC01B	21.39	5.64	.66
16.	Letter Grouping NSC01A	58.02	12.11	.83
17.	Memory for Nonsense Word Classes MSC02B	5.67	3.69	.82[a]
18.	Memory for Word Classes MSC04A	22.12	10.45	.75
19.	Multiple Figural Similarities DFC07A	10.64	2.49	.42
20.	Multiple Grouping DMC02C	7.53	1.67	.54
21.	Multiple Grouping of Figures DFC08A	13.98	3.18	.66
22.	Multiple Grouping of Nonsense Words DSC05A	5.01	2.58	.75
23.	Multiple Letter Similarities DSC04A	10.72	3.36	.59
24.	Name Grouping DSC02B	8.02	2.60	.66
25.	Naming Meaningful Trends NMU04A	3.96	2.29	.30[b]
26.	Number Classification CSC03C	9.88	4.80	.73
27.	Number-Group Naming CSC05B	7.44	2.41	.71[a]
28.	Picture Class Memory MMC03B	14.98	4.90	.67[a]
29.	Picture-Group Naming NMU03A	4.56	1.73	.50[a]
30.	Problem Solving CMS05A	4.22	3.31	.75[a]
31.	Restricted Figural Classifications NFC04A	15.15	8.98	.46
32.	Restricted Symbolic Classifications NSC04A	11.58	9.57	.65
33.	Sentence Classification CMC03A	17.53	6.49	.72
34.	Ship Destination Test CMS02D	9.38	6.69	.87[a]
35.	Suffixes DSU01A	12.44	4.51	.63[b]
36.	Utility Test DMC01A	14.99	5.97	.72
37.	Verbal Classification CMC02B	43.47	15.54	.74
38.	Verbal Comprehension CMU02C	10.44	4.31	.75[a]
39.	Word Classification CMC01B	12.82	3.33	.52[a]
40.	Word Completion CMU01B	10.14	3.33	.77[a]
41.	Word Fluency DSU02A	42.27	9.94	.79
42.	Word-Group Naming NMU02A	11.36	2.56	.61[a]
43.	Word Grouping NMC01B	41.59	5.20	.50
44.	Sex	.45	.50	

[a]Kuder-Richardson estimate of reliability.

[b]Obtained communality as a lower-bound estimate of reliability.

Table 3

Correlation Matrix of 44 Variables

	Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.	Alternate Letter Groups		35	38	18	33	30	35	42	43	27	25	28	34	30	38	39
2.	Alternate Uses	35		30	35	32	25	36	28	29	23	22	38	32	21	26	30
3.	Classified Information	38	30		30	37	25	24	29	30	22	31	41	37	38	25	34
4.	Concept Grouping	18	35	30		36	37	34	41	42	36	33	45	47	47	45	51
5.	Figural Class Inclusion	33	32	37	36		50	51	50	50	39	28	53	49	53	37	50
6.	Figural Hierarchical Grouping	30	25	25	37	50		45	53	57	43	30	39	45	36	38	45
7.	Figure Classification	35	36	24	34	51	45		37	45	34	20	40	36	33	29	36
8.	Figure-Concept Grouping	42	28	29	41	50	53	37		49	41	30	43	53	47	45	65
9.	Figure Exclusion	43	29	30	42	50	57	47	49		37	31	46	53	43	45	34
10.	Figure Grouping	27	23	22	36	39	43	34	41	37		17	34	33	28	38	43
11.	Group Classification	25	22	31	33	28	30	20	30	31	17		37	42	32	27	43
12.	Largest Class	28	38	41	45	53	39	40	43	46	34	37		41	41	44	39
13.	Letter Classification	34	32	37	47	49	45	36	53	53	33	42	41		47	50	61
14.	Letter-Concept Grouping	30	21	38	47	53	36	33	47	43	28	32	41	47		45	53
15.	Letter-Group Exclusion	38	26	25	45	37	38	29	45	45	38	27	44	50	45		54
16.	Letter Grouping	39	30	34	51	50	45	36	65	34	43	43	39	61	53	54	
17.	Memory for Nonsense Word Classes	25	32	39	22	4[illegible]	32	33	45	41	43	21	53	44	39	45	55
18.	Memory for Word Classes	28	26	32	28	45	28	30	42	40	24	27	38	39	37	29	36
19.	Multiple Figural Similarities	25	20	11	18	31	26	25	24	31	14	12	25	24	33	22	28
20.	Multiple Grouping	32	38	18	27	15	26	16	28	30	16	25	24	20	15	15	14
21.	Multiple Grouping of Figures	51	40	43	40	47	42	48	48	48	35	21	32	49	41	38	50
22.	Multiple Grouping of Nonsense Words	29	23	22	31	37	37	23	44	29	20	36	33	46	41	36	51
23.	Multiple Letter Similarities	38	25	32	28	30	30	35	32	33	22	25	34	43	41	35	49
24.	Name Grouping	27	31	30	27	32	23	24	24	29	17	18	36	31	31	27	26
25.	Naming Meaningful Trends	24	26	20	16	12	08	18	14	19	07	18	20	18	11	11	13
26.	Number Classification	37	35	35	40	52	43	51	45	45	36	34	38	56	54	46	47
27.	Number-Group Naming	44	34	39	41	47	31	51	50	35	31	28	35	46	47	40	46
28.	Picture Class Memory	26	21	21	25	36	31	22	41	24	29	14	30	39	31	19	29
29.	Picture-Group Naming	20	35	26	43	40	29	32	37	27	26	19	41	36	31	30	38
30.	Problem Solving	36	24	28	39	51	49	43	57	48	27	25	41	39	40	35	35
31.	Restricted Figural Classifications	41	28	35	37	41	40	30	50	48	39	26	38	49	51	45	46
32.	Restricted Symbolic Classifications	30	27	39	52	41	51	27	42	45	36	35	36	40	49	46	42
33.	Sentence Classification	20	26	40	37	45	33	26	35	35	22	30	40	40	40	41	37
34.	Ship Destination Test	44	34	37	38	54	51	45	59	49	32	23	47	43	43	42	52
35.	Suffixes	30	25	19	37	19	14	21	31	21	18	35	33	31	34	34	40
36.	Utility Test	37	55	25	20	25	19	24	25	17	18	17	23	21	12	18	37
37.	Verbal Classification	37	41	48	56	57	41	52	47	49	36	39	60	45	41	35	48
38.	Verbal Comprehension	19	35	36	57	36	33	35	40	38	24	31	44	39	31	31	43
39.	Word Classification	23	30	26	45	40	35	36	41	31	25	40	37	36	32	26	27
40.	Word Completion	26	34	40	63	41	36	40	49	36	26	42	49	38	40	36	43
41.	Word Fluency	30	40	24	46	28	20	25	30	29	15	32	36	41	35	44	36
42.	Word-Group Naming	35	44	30	51	44	31	38	44	38	33	32	47	33	42	34	38
43.	Word Grouping	25	34	48	52	47	33	31	38	28	29	37	45	40	41	39	47
44.	Sex	09	-00	-14	-09	11	16	22	15	11	10	-12	-05	-05	-02	-13	-08

Note. —Decimal points omitted

At the end of the 96th trial, each S was told to give a name or verbal description of each of the four concepts belonging to the four labels, respectively. The number of acceptable verbalizations out of four was the verbalization score.

The third kind of score may be called a "mastery" score.[7] It follows the traditional principle of scoring in terms of the number of trials needed to achieve a criterion of mastery. This was done for each concept in each task. The criterion of mastery was that trial at which the last error occurred, out of the 24 trials given for each concept. No verbalization of concepts was required in connection with this score, hence one might expect that its factor composition would be somewhat different from that for the verbalization score. Both the verbalization and mastery scores should be indicators of rates of learning of individuals, since all Ss had equivalent opportunities in the tasks.

[7] The use of this score was suggested by Dr. Langdon E. Longstreth.

Statistical Treatment and Results

Descriptive Statistics for the Tests

Table 2 presents the statistical information concerning the test scores, including means, standard deviations, and estimates of reliabilities.[8] The score distributions of four tests were too severly skewed or truncated to meet the requirement for computing a Pearson r, so they were dichotomized near their medians. Those tests were Concept Grouping, Memory for Nonsense Word Classes, Letter Grouping, and Restricted Figural Classifications. For all tests with two or more separately timed parts, Spearmen-Brown adjustments of inter-part correlations were used as estimates of reliability.

[8] For the statistical analyses, computer assistance was obtained from Health Sciences Computer Facility, U.C.L.A., sponsored by NIH Grant FR-3, Western Data Processing Center, U.C.L.A., and Computer Sciences Laboratory, U.S.C.

Table 3 (Continued)

17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
25	28	25	32	51	29	38	27	24	37	44	26	20	36	41	30	20	44	30	37	37	19	23	26	30	35	25	09
32	26	20	38	40	23	25	31	26	35	34	21	35	24	28	27	26	34	25	55	41	35	30	34	40	44	34	-00
39	32	11	18	43	22	32	28	20	35	39	21	26	28	35	39	40	37	19	25	48	36	26	40	24	30	48	-14
22	28	18	27	40	31	28	27	16	40	41	25	43	39	37	52	37	38	37	20	56	57	45	63	46	51	52	-09
47	45	31	15	47	37	30	32	12	52	47	36	40	51	41	41	45	54	19	25	27	36	40	41	28	44	47	11
32	28	26	26	42	37	30	23	08	43	31	31	29	49	40	51	33	51	14	19	41	33	35	36	20	31	33	16
33	30	25	16	48	23	35	24	18	51	51	22	32	43	30	27	26	45	21	24	52	35	36	40	25	38	31	22
45	42	24	28	48	44	32	24	14	45	50	41	37	57	50	42	35	59	31	25	47	40	41	49	30	44	38	15
41	40	31	30	48	29	33	29	19	45	35	24	27	48	48	45	35	49	21	17	49	38	31	36	29	38	28	11
43	24	14	16	35	20	22	17	07	36	31	29	26	27	39	36	22	32	18	18	36	24	25	26	15	33	29	10
21	27	12	25	21	36	25	18	18	34	28	14	19	25	26	35	30	23	35	17	39	31	40	42	32	32	37	-12
53	38	25	24	32	33	34	36	20	38	35	30	41	41	38	36	40	47	33	23	60	44	37	49	37	47	45	-05
44	39	24	20	49	46	43	31	18	56	46	39	36	39	49	40	40	43	31	21	45	39	36	38	41	33	40	-05
39	37	33	15	41	41	15	31	11	54	47	31	31	40	51	49	40	43	34	12	41	31	32	40	35	42	41	-02
45	29	22	15	38	36	35	27	11	46	40	19	30	35	45	46	41	42	34	18	35	31	26	36	44	34	39	-13
55	36	28	14	50	51	49	26	13	47	46	29	38	35	46	42	37	52	40	37	48	43	27	43	36	38	47	-08
	70	11	14	45	24	37	39	03	46	34	25	36	23	36	31	33	34	19	18	42	36	22	33	27	26	35	-32
70		25	11	36	30	31	22	-01	41	37	30	24	32	32	30	39	33	32	11	48	28	22	42	24	25	32	-07
11	25		21	30	26	27	14	08	29	14	28	12	27	26	29	10	18	14	20	22	15	14	16	22	18	23	08
14	11	21		23	27	30	21	24	23	13	13	24	21	18	28	03	14	22	44	30	20	18	29	27	27	14	-09
45	36	30	23		38	41	39	18	51	47	27	32	36	49	36	32	42	28	35	46	36	31	36	40	42	28	07
24	30	26	27	38		41	35	12	45	35	25	30	42	42	32	28	36	35	32	37	29	29	32	41	24	26	-04
37	31	27	30	41	41		30	15	43	39	17	27	34	42	26	29	33	28	22	41	36	22	32	30	26	31	-11
39	22	14	21	39	35	30		20	39	32	16	28	28	32	22	26	26	36	40	32	39	23	38	49	34	32	19
03	-01	08	24	18	12	15	20		23	20	10	29	10	18	16	12	19	13	20	27	19	16	20	16	29	25	07
46	41	29	23	51	45	43	39	23		61	26	42	47	52	40	44	47	30	25	53	42	43	45	38	42	40	03
34	37	14	13	47	35	39	32	20	61		34	44	48	46	39	38	48	30	15	49	41	38	43	33	37	44	12
25	30	28	13	27	25	17	16	10	26	34		23	33	20	19	22	33	12	11	26	25	20	20	21	32	27	11
36	24	12	24	32	30	27	28	29	42	44	23		29	30	33	24	30	24	36	49	30	28	41	32	39	41	02
23	32	27	21	36	42	34	28	10	47	48	33	29		44	41	35	60	29	17	50	42	43	46	26	38	38	37
36	32	26	18	49	42	42	32	18	52	46	20	30	44		44	42	46	35	16	39	41	35	34	39	38	34	12
31	30	29	28	36	32	26	22	16	40	39	19	33	41	44		34	47	23	08	38	25	32	31	27	23	47	07
33	39	10	03	32	28	29	26	12	44	38	22	24	35	42	34		34	25	14	48	43	43	44	39	37	38	-04
34	33	18	14	42	36	33	26	19	47	48	33	30	60	46	47	34		17	20	50	49	38	47	16	45	35	28
19	32	14	22	28	35	28	36	13	30	30	12	24	29	35	23	25	17		24	28	27	29	36	59	34	37	-07
18	11	20	44	35	32	22	40	20	25	15	11	36	17	16	08	14	20	24		27	25	23	33	40	31	25	-01
42	48	22	30	46	37	41	32	27	53	49	26	49	50	39	38	48	50	28	27		50	45	59	32	54	50	04
36	28	15	20	36	29	36	39	19	42	41	25	30	42	41	25	43	49	27	25	50		39	71	33	47	50	-05
22	22	14	18	31	29	22	23	16	43	38	20	28	43	35	32	43	38	29	23	45	39		52	34	43	41	03
33	29	16	29	36	32	32	38	20	45	43	20	41	46	34	31	44	47	36	33	59	71	52		36	56	56	-07
27	24	22	27	40	41	30	49	16	38	33	21	32	26	39	27	39	16	59	40	32	33	34	36		39	36	-15
26	25	18	27	42	24	26	34	29	42	37	32	39	38	38	23	37	45	34	31	54	47	43	56	39		37	13
35	32	23	14	28	26	31	32	25	40	44	27	41	38	34	47	38	35	37	25	50	50	41	56	36	37		-13
-32	-07	08	-09	07	-04	-11	-19	07	03	12	11	02	37	12	07	-04	28	-07	-01	04	-05	03	-07	-15	13	-13	

Kuder-Richardson estimates were computed for all one-part tests that showed no material evidence of speeding. For one-part speeded tests, communalities are given as lower-bound estimates of communalities.

A matrix of the intercorrelations of the 43 tests and the variable of Sex is given in Table 3. For variables that had been dichotomized, point-biserial and phi coefficients came from the computer. Corresponding Pearson r's were estimated by applying appropriate formulas (Guilford, 1965, pp. 324, 354).

Factor Analysis of Tests

For the extraction of factors, estimates were made for the communalities of the 44 variables, using the multiple-R squared, then iterating extractions to obtain better estimates, assuming 16 factors (the number hypothesized). The extraction of principal axes was accomplished by means of the program BMD 03M (Dixon, 1965). Iterations were continued until no communality changed more than .05 in going from one cycle to the next. The principal-axes matrix is given in Table 4.

The axes were rotated orthogonally to psychological interpretability by means of an analytic procedure developed by Cliff (1966). This procedure provides a least-squares fit of a matrix to a specified target matrix. The first target matrix was constructed by giving each variable a loading equal to the square root of its communality for the factor on which it was expected to appear after rotation, with other loadings being set equal to zero. The resulting rotated matrix indicated that some variables would not meet satisfactorily their targeted major loadings. The target values for further rotations were changed accordingly in the next target matrix. In this manner a sequence of rotations was carried out, with the accepted solution that appears in Table 5. In the rotation process the conditions of positive manifold and simple structure were also well approximated.

The Data from the Learning Tasks

It may be recalled that the learning-task performances were scored in three different ways. Stage scores were derived from blocks of eight trials each, giving 12 measures for each S for each task. Verbalization scores were derived for each learning task from the number of concepts that S could describe adequately at the end of the 96 trials. The mastery score was the number of the trial, out of 24, at which it could be inferred that he had learned the concept, whether he could later verbalize it or not. In this case learning with respect to each concept was quantified.

The Stage Scores. From the stage scores, means were obtained over all subjects for all three tasks in order to plot learning curves as shown in Fig. 1. In spite of the fact that the stage scores were estimated to have a fair degree of reliability (correlations between immediately neighboring stage scores ranged from .47 to .76) the learning curves are rather irregular.

The very first stage scores were generally above the chance level of 2.0, indicating that there was some degree of learning during the first eight trials. One or two of the concepts were quite easy to learn. For the figural and symbolic tasks, the trends in the curves were essentially linear. For the semantic task there was an observable trace of positive acceleration. The semantic learning problem was a little different from the other two, in that the exemplars had to be isolated from a set of four words at each trial. The rate of learning was lowest for the symbolic task, in which two concepts proved to be particularly difficult. These two could be verbalized by only 11 and 21 per cent of the Ss at the end of practice. Possibly more than these percentages had actually learned the concepts. At the end of practice all three stage scores were below the maximum possible score of 8, simply reflecting the fact that not all Ss had learned all concepts in any task.

Table 4

Principal-Axes Factor Matrix

Test Name	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	h^2
1. Alternate Letter Groups	55	-06	15	38	03	07	18	-16	-12	-04	26	05	-09	-04	05	01	64
2. Alternate Uses	52	22	26	15	23	-04	01	01	11	02	06	-02	02	-05	01	08	96
3. Classified Information	54	12	-09	-07	18	00	31	-25	-14	09	14	-17	03	-06	00	04	50
4. Concept Grouping	67	16	07	-32	-18	-19	-07	01	20	-09	-04	01	-17	03	05	12	49
5. Figural Class Inclusion	70	-22	-06	-03	16	03	-02	08	07	17	-09	-10	10	-13	01	-10	68
6. Figural Hierarchical Grouping	61	-31	02	04	-04	-28	-04	10	-02	-10	-09	-04	15	-07	01	06	69
7. Figure Classification	59	-22	16	02	21	13	03	05	11	-07	20	18	-05	-11	22	00	59
8. Figure-Concept Grouping	71	-23	-02	06	-07	-06	-27	-02	-10	01	17	05	01	09	-09	08	45
9. Figure Exclusion	66	-23	-01	10	03	-17	19	23	00	-22	01	04	-03	-05	-05	-04	63
10. Figure Grouping	50	-17	-08	05	08	-15	-13	-03	20	-11	09	04	01	-02	02	03	75
11. Group Classification	49	18	-03	-12	-20	-15	10	01	-20	14	07	25	11	-18	-03	-02	60
12. Largest Class	66	06	-05	-13	15	-08	03	16	03	05	07	-02	02	03	-04	-24	80
13. Letter Classification	70	-03	-18	08	-13	-02	-03	-05	00	-01	-08	07	-01	-13	-20	08	67
14. Letter-Concept Grouping	65	-07	-18	-01	-19	05	08	-03	06	08	-07	-09	-10	00	-02	-10	59
15. Letter-Group Exclusion	62	02	-21	07	-19	-06	-02	-04	15	-18	07	-02	03	01	02	-09	71
16. Letter Grouping	73	02	-23	12	-15	-08	-37	-30	-04	03	01	06	-05	-13	12	-10	61
17. Memory for Nonsense Word Classes	60	09	-57	12	44	-01	-11	09	03	-08	07	04	06	13	01	-01	58
18. Memory for Word Classes	55	-05	-38	05	21	11	02	26	-09	20	12	10	-06	07	09	12	72
19. Multiple Figural Similarities	36	-10	04	24	-10	-10	06	17	01	20	-16	-19	-27	-09	11	-06	64
20. Multiple Grouping	37	24	30	27	03	-36	11	12	-13	01	-02	13	-06	18	-08	08	48
21. Multiple Grouping of Figures	66	-05	02	26	08	11	05	-07	05	-15	-02	-03	-08	-11	03	12	47
22. Multiple Grouping of Nonsense Words	56	06	-03	21	-28	04	-12	02	-20	11	-19	01	13	06	-09	-05	71
23. Multiple Letter Similarities	55	07	-10	18	-04	05	08	-10	-19	-05	-18	07	-15	06	05	-09	51
24. Naming Grouping	50	32	03	12	07	18	04	09	-02	-13	-09	-21	10	12	-05	-05	78
25. Naming Meaningful Trends	28	12	28	01	07	-02	17	-17	07	03	01	08	-03	04	-17	-14	67
26. Number Classification	72	-06	-04	05	-01	18	10	-04	05	-02	-25	10	06	01	-06	06	30
27. Number-Group Naming	67	-12	01	-04	00	29	07	-23	08	06	-05	12	-03	13	-01	17	74
28. Picture Class Memory	43	-17	-01	05	04	02	-15	06	04	25	08	-14	-20	-04	-26	14	40
29. Picture-Group Naming	55	12	11	-04	14	-03	-10	-13	27	15	-13	09	09	22	-10	-06	66
30. Problem Solving	65	-35	20	-09	-12	10	-02	15	-18	05	00	-08	09	20	07	01	63
31. Restricted Figural Classifications	65	-11	-06	10	-19	11	10	-05	01	-17	05	-06	02	05	-06	-05	53
32. Restricted Symbolic Classifications	60	-16	-09	-04	-21	-33	25	-09	16	05	04	-11	11	13	11	08	68
33. Sentence Classification	57	03	-13	-23	-03	15	10	05	-02	-02	04	-08	15	-18	-07	03	64
34. Ship Destination Test	68	-35	11	-07	06	01	-07	-12	-14	-09	10	-11	05	06	00	-10	58
35. Suffixes	48	33	02	06	-33	20	-04	15	04	06	22	13	-02	10	17	-06	46
36. Utility Test	42	38	40	38	20	-07	-22	-06	-04	06	-02	-13	18	-10	11	04	67
37. Verbal Classification	75	01	08	-19	21	-02	09	03	-04	10	-04	16	-02	-02	03	-10	63
38. Verbal Comprehension	63	15	10	-35	09	04	-12	00	-21	-22	-08	-14	-16	03	-01	05	57
39. Word Classification	56	03	15	-25	-07	03	02	09	-03	02	00	08	15	-12	-02	12	55
40. Word Completion	69	21	18	-40	05	-03	-11	01	-18	-09	-03	01	-06	03	07	04	73
41. Word Fluency	56	44	06	14	-27	20	00	21	19	-04	05	-07	05	-05	-02	05	55
42. Word-Group Naming	63	07	28	-14	08	07	-07	07	11	-05	16	04	-14	-10	-14	-13	55
43. Word Grouping	63	18	-04	-28	-01	-07	06	-15	07	22	02	-15	-01	03	15	01	91
44. Sex	02	-62	47	02	-06	16	-06	03	08	06	10	01	05	02	06	-04	71
Eigenroots	15.22	1.95	1.59	1.39	1.13	.84	.73	.69	.63	.59	.53	.49	.45	.43	.39	.33	

Note. — Decimal points omitted except for eigenroots

Table 5

Rotated Factor Matrix

	Test Name	CFC	CSC	CMU	CMC	CMS	MSC	MMC	DFC	DSU	DSC	DMC	NFC	NSC	NMU	NMC	SEX	h^2
1.	Alternate Letter Groups	00	13	-04	21	22	12	11	57	08	13	26	14	19	15	-06	-02	64
2.	Alternate Uses	17	06	13	17	01	14	15	20	14	08	46	05	-01	29	05	-01	95
3.	Classified Information	-01	13	13	33	18	20	40	22	-05	05	17	-13	20	11	17	-20	50
4.	Concept Grouping	20	26	49	07	05	-01	06	05	29	-06	13	18	20	26	37	-11	49
5.	Figural Class Inclusion	46	17	06	26	16	25	26	10	00	18	08	11	18	14	25	18	68
6.	Figural Hierarchical Grouping	42	20	11	16	19	02	11	05	-04	09	19	41	28	-01	12	01	70
7.	Figure Classification	47	28	19	23	17	19	-12	25	-02	02	17	01	05	18	03	20	60
8.	Figure-Concept Grouping	08	21	18	11	25	22	18	16	11	15	11	50	27	14	13	19	45
9.	Figure Exclusion	44	21	07	21	23	10	04	27	02	14	09	38	10	09	11	-21	63
10.	Figure Grouping	26	13	10	09	01	21	07	12	04	-05	08	32	27	20	05	02	75
11.	Group Classification	-09	22	09	41	05	01	-03	07	11	15	18	16	13	-04	43	-07	59
12.	Largest Class	27	01	14	26	19	27	12	05	10	21	09	15	09	28	34	-11	80
13.	Letter Classification	15	43	14	20	-03	14	19	17	09	27	05	28	24	10	19	-01	68
14.	Letter-Concept Grouping	23	29	10	10	15	12	18	20	17	24	-09	06	30	13	28	-03	59
15.	Letter-Group Exclusion	19	20	12	15	03	16	06	13	26	17	-02	23	41	18	10	-16	71
16.	Letter Grouping	03	19	28	15	-08	28	04	21	08	29	10	23	61	13	22	20	61
17.	Memory for Nonsense Word Classes	20	13	10	12	-01	82	15	00	00	19	07	19	19	12	05	-22	58
18.	Memory for Word Classes	16	21	03	12	17	63	14	17	13	09	03	14	-01	-11	25	-01	73
19.	Multiple Figural Similarities	35	05	00	-18	06	-02	10	35	07	22	12	01	10	-08	27	06	64
20.	Multiple Grouping	-01	10	03	-07	15	-04	-06	17	04	18	57	23	-07	13	17	-24	48
21.	Multiple Grouping of Figures	27	29	16	17	05	19	16	40	11	17	20	12	18	15	-09	00	47
22.	Multiple Grouping of Nonsense Words	04	30	04	07	15	03	07	03	19	51	19	16	24	-02	16	10	71
23.	Multiple Letter Similarities	07	29	17	06	16	18	-03	28	00	37	12	-01	22	07	11	-09	51
24.	Name Grouping	15	10	17	12	11	17	19	02	28	39	22	-07	03	19	-07	-18	77
25.	Naming Meaningful Trends	-02	10	00	14	09	-11	05	14	-04	09	19	-04	-02	40	10	-06	67
26.	Number Classification	28	53	13	22	16	17	10	13	10	25	11	04	15	19	08	04	29
27.	Number-Group Naming	08	53	17	17	26	22	18	20	12	03	05	-01	17	27	04	16	74
28.	Picture Class Memory	11	15	07	-08	03	14	40	21	04	10	01	27	-04	11	22	21	39
29.	Picture-Group Naming	14	26	08	03	08	19	10	-10	08	10	27	02	14	51	20	08	66
30.	Problem Solving	27	20	16	14	60	03	14	08	16	16	08	24	12	04	12	21	64
31.	Restricted Figural Classifications	18	29	09	19	24	06	15	23	21	23	-03	19	29	17	00	-09	54
32.	Restricted Symbolic Classifications	26	27	-01	07	27	-01	20	07	13	-12	16	17	47	07	29	-22	68
33.	Sentence Classification	18	22	19	44	09	13	27	01	18	12	-06	06	09	05	17	-04	64
34.	Ship Destination Test	23	09	22	25	43	10	21	18	-06	13	04	28	29	21	03	15	58
35.	Suffixes	-09	10	09	15	12	14	-12	18	62	19	10	03	12	11	21	00	46
36.	Utility Test	07	-12	12	12	-09	06	12	13	16	29	73	00	09	18	-08	15	67
37.	Verbal Classification	24	22	24	35	26	25	05	14	-02	12	20	06	04	28	36	02	62
38.	Verbal Comprehension	12	11	68	19	22	10	17	05	07	20	08	09	02	17	13	-07	57
39.	Word Classification	16	25	25	38	16	-01	11	-01	19	03	16	14	01	08	22	07	55
40.	Word Completion	08	13	62	29	25	10	07	00	13	12	21	09	05	20	28	-01	73
41.	Word Fluency	12	19	12	17	-09	05	10	13	66	29	20	03	04	16	10	-10	55
42.	Word-Group Naming	18	04	28	29	10	04	11	24	18	12	10	21	-07	45	21	08	55
43.	Word Grouping	10	14	29	18	16	16	27	03	18	-01	16	-13	29	19	42	-03	90
44.	Sex	23	-04	-15	02	38	-27	-02	15	-03	-19	-06	17	-04	11	-16	49	71

Note. —Decimal points omitted

All the stage scores for each task were correlated with all the tests in the analyzed battery. The resulting coefficients are presented in Table 6. It will be noted that except at stages 1 and 2, the correlations are overwhelmingly positive and that coefficients above .3 and even above .4 are encountered, indicating good promise for finding representation of the common factors in the stage scores. The correlations with the Sex variable are both positive and negative, fluctuating around zero, which tells us that there is no systematic sex difference in performance in the learning tasks and that we are justified in treating data from the two sexes together.

In order to estimate loadings for the stage scores on the common factors represented in the test battery, an extension procedure developed by Dwyer (1937) and Mosier (1938) was utilized. The results of applying this procedure are presented in Table 7. Like the correlation coefficients from which they came, the factor loadings are predominatly positive, with a tendency for the negative loadings to appear in the earlier trials. Where all 12 of the loadings for a task were positive on a factor, we may have some confidence that the factor made some contribution to learning in that task, however trivial. Of course it must be remembered that there is lack of independence of the loadings in a set of 12, since the stage scores were intercorrelated, hence a sign test of significance does not apply. Further consideration of the possible significance of the loadings will be given in the discussion of the results.

The Verbalization Scores. Table 8 presents the descriptive data for the verbalization scores, for each concept separately and for a combination of the four concepts of each task. The means for the single concepts are clear indices of the difficulty levels for the various concepts. It will be seen that the best levels of difficulty in terms of homogeneity were achieved for the semantic task, where the range of means was .51 to .77. The over-all difficulty levels were almost exactly equal for the figural and semantic tasks. The symbolic task was more difficult on the

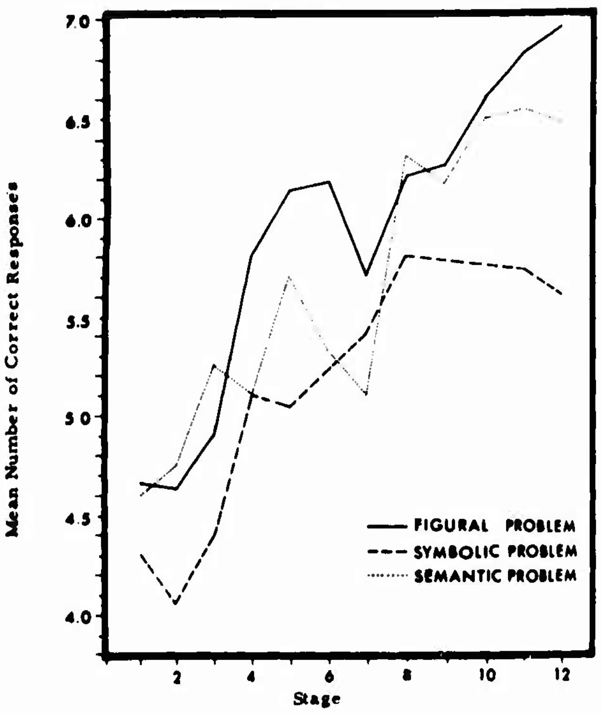

Fig. 1. Learning curves for the three concept-learning tasks, based upon stage scores.

whole, and its concepts varied widely in difficulty. It is not known what such conditions may contribute to factorial results. There is some possibility of extracting some kind of an answer to this question when factor loadings of the mastery scores for the single concepts are examined.

Table 9 presents the correlation matrix for tests with verbalization scores from the three tasks, respectively. The coefficients range higher than those for correlations of stage scores with the same tests. The coefficients are all positive, indicating much basis for expecting that all of the common factors in the tests make their contributions to almost all task scores.

The estimation of factor loadings for the three verbalization scores showed the results seen in Table 10. In view of the general level of the correlation coefficients in Table 9, these loadings seem to be unexpectedly small. But they are comparable with the loadings of the stage scores on the same factors. The same apparent discrepancy exists between general size of correlations between stage scores and test scores and factor loadings for the stage scores. A general hypothesis for this would be that there were aptitude factors in common to learning scores and test scores other than the 15 that were brought out in the factor analysis. If so, those factors are well scattered among the tests, one factor to a test, otherwise the analysis of the tests should have detected them.

The Mastery Scores. The mastery scores were obtained for each concept separately, yielding 12 values. Some difficulties were encountered in applying the principle of adopting the number of the trial on which the last error occurred. When this came near the end of the series of 24 trials for a concept, one could not be assured that that concept had been achieved even though two or three correct repsonses followed. In other cases, there might be a string of correct responses too near the end, with one exceptional wrong response near the end. The scoring principle was arbitrarily followed in all cases.

Many of the score distributions were truncated near zero or near . 24. The easiest concepts were mastered in one or two trials by one-half or more of the Ss, and the most difficult concepts had not been mastered at the end of 24 trials by large numbers of Ss. Consequently, all score distributions were dichotomized near their medians for the purposes of correlation and estimation of factor loadings. The data on score distributions and intercorrelations for the mastery scores are not presented here. For purposes of the correlational analysis and estimation of factor loadings, the mastery scores were reflected so that degree of mastery would not be inversely related to test scores. The estimated factor loadings are presnted in Table 11.

Table 6

Correlations Between Tests and Stage Scores for the Three Concept-Learning Tasks

Figural Task Stages

Test	1	2	3	4	5	6	7	8	9	10	11	12
1.	11	07	06	09	17	20	13	17	21	26	15	26
2.	09	16	15	15	21	19	27	23	14	27	19	20
3.	04	09	08	12	2[illegible]	19	18	24	33	30	23	21
4.	-06	03	08	17	17	17	20	17	24	29	22	24
5.	11	-01	14	19	26	30	32	37	37	43	33	38
6.	19	14	27	26	33	31	37	42	39	43	33	40
7.	00	03	11	14	20	22	24	28	26	32	27	26
8.	12	12	26	36	26	39	35	45	41	47	35	47
9.	06	08	20	15	25	23	31	31	31	32	20	34
10.	19	08	13	14	21	22	31	25	22	32	23	26
11.	19	17	12	17	08	12	19	26	24	30	18	21
12.	05	06	11	24	27	33	30	25	34	42	27	28
13.	08	16	15	23	21	22	29	32	30	37	26	31
14.	08	04	13	25	18	30	29	25	28	32	26	29
15.	16	20	15	20	25	28	34	23	29	32	24	34
16.	18	21	22	27	19	36	40	36	37	43	35	34
17.	18	17	24	27	33	34	29	31	30	35	27	25
18.	11	11	20	29	34	35	33	40	42	42	31	25
19.	24	11	16	20	20	16	24	19	23	19	15	20
20.	11	-01	12	12	04	04	02	21	09	14	-02	05
21.	10	10	19	18	26	29	26	31	38	36	25	36
22.	15	15	14	31	14	21	24	33	30	31	28	31
23.	04	03	10	08	12	18	17	16	17	20	17	19
24.	13	16	14	28	23	22	23	23	21	29	19	28
25.	06	05	13	13	16	10	15	09	17	19	08	10
26.	14	16	14	22	24	24	34	36	31	39	36	37
27.	-06	04	01	11	15	24	25	27	29	36	27	26
28.	02	08	10	29	24	13	21	22	31	32	26	23
29.	-12	07	06	17	24	29	26	27	26	27	23	20
30.	-05	-04	07	17	19	14	17	27	30	38	28	32
31.	03	10	14	21	25	28	24	26	27	33	29	35
32.	01	06	06	11	09	09	22	22	22	20	17	23
33.	02	03	04	15	24	16	21	19	25	30	31	29
34.	-02	08	07	15	16	20	20	24	25	33	29	34
35.	08	21	06	20	07	20	25	23	19	36	30	22
36.	12	11	10	15	18	17	14	18	11	23	14	16
37.	-05	00	09	19	29	30	31	30	39	40	33	31
38.	-02	07	04	18	17	19	23	23	30	33	26	31
39.	07	06	02	13	14	16	22	27	26	39	26	29
40.	-02	07	04	26	14	26	21	29	29	34	27	31
41.	07	13	07	15	13	11	17	17	17	27	27	24
42.	00	03	06	17	24	21	21	22	22	30	24	30
43.	14	15	12	27	25	34	37	31	39	44	40	31
44.	-09	-12	04	-04	-01	-08	-08	-00	02	-04	05	04

Table 6 (Continued)

Symbolic Task Stages												Semantic Task Stages											
1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
-05	06	21	14	17	22	16	17	20	21	26	28	01	23	16	15	16	20	18	30	28	24	25	23
09	02	10	08	15	17	12	12	12	15	16	20	18	21	23	30	30	32	29	26	30	30	28	19
-00	07	11	12	17	31	28	18	20	21	24	14	05	22	25	22	33	33	35	42	37	42	40	47
04	06	10	08	17	16	08	15	12	15	12	14	01	15	12	16	23	21	30	37	35	33	31	30
-05	-07	-02	09	18	23	21	24	25	26	28	21	02	23	25	16	26	39	38	47	37	38	40	41
08	-00	21	22	26	30	23	22	31	34	28	17	14	28	31	15	29	29	24	35	34	34	34	36
-10	-09	12	11	07	18	12	28	18	24	20	11	-01	15	15	12	09	20	19	25	30	29	28	27
08	04	19	18	25	27	25	28	29	33	26	27	17	39	35	27	36	45	28	43	41	40	36	39
-01	-03	12	02	10	21	19	19	19	21	26	14	01	21	19	13	27	27	29	37	29	31	38	35
02	08	10	09	16	19	18	14	23	15	15	19	08	19	19	15	21	28	23	32	33	32	24	37
10	-01	10	01	06	02	-05	03	09	12	12	12	07	11	14	04	27	16	16	30	29	35	29	38
-00	08	20	16	22	33	25	23	35	26	26	16	06	18	28	17	28	33	31	43	35	35	39	38
00	00	16	10	16	22	29	23	27	32	34	22	09	35	30	25	37	43	30	45	43	46	44	40
09	04	16	16	32	33	30	34	32	35	29	33	06	24	30	25	28	44	34	45	41	34	42	35
03	03	18	13	24	26	28	24	25	26	28	29	12	30	33	22	28	33	27	38	34	31	35	35
07	-01	18	14	27	16	21	20	24	30	23	24	10	30	27	26	34	47	34	43	34	40	40	34
05	08	15	16	19	20	21	08	20	20	23	11	17	31	25	24	26	31	38	45	33	36	36	31
-00	01	09	10	15	21	18	22	23	27	28	22	17	27	32	31	31	31	40	48	36	35	39	38
-05	11	15	14	16	18	20	22	16	18	21	19	09	17	15	16	14	23	24	21	20	19	16	20
-03	-02	05	02	06	10	02	-00	09	04	07	09	01	18	05	07	15	11	14	19	16	24	12	25
-10	03	07	13	11	23	26	20	22	29	27	21	08	31	24	26	26	37	35	40	42	44	37	38
02	-07	17	15	19	17	23	23	32	30	20	28	10	28	19	15	24	24	16	28	27	29	24	29
07	06	19	19	22	21	23	28	33	30	26	22	13	28	29	28	24	32	30	36	41	38	31	31
15	19	17	16	23	22	23	21	22	21	29	21	10	25	20	25	26	25	32	32	24	24	31	24
01	-07	01	-02	03	00	09	05	05	15	18	13	-03	14	09	14	23	23	05	19	21	20	16	20
-09	-02	08	10	17	26	22	21	28	30	28	25	11	33	24	28	34	37	34	45	44	38	34	35
-06	-07	10	03	13	22	18	27	19	27	30	35	01	25	19	19	21	33	31	43	40	31	33	35
06	03	19	10	14	18	20	27	15	20	27	21	03	17	19	09	13	25	20	37	32	35	35	41
-07	-07	-02	02	14	11	14	27	18	23	21	18	-06	14	06	16	23	28	25	31	29	28	37	25
-08	-05	16	04	18	25	24	33	30	34	31	28	06	22	19	11	18	29	23	34	34	29	28	29
07	07	10	13	17	23	27	27	33	30	28	28	10	28	28	30	34	35	27	37	38	38	31	36
-03	00	09	03	12	14	10	12	13	19	15	13	03	17	17	16	27	27	22	28	17	25	26	25
04	-02	09	05	11	15	19	16	26	24	23	18	-11	08	23	13	21	25	23	29	25	32	29	34
-03	-04	14	11	15	31	23	21	30	33	31	20	-01	10	21	17	26	32	24	38	33	31	32	29
08	13	10	05	16	18	16	12	16	13	14	18	10	23	15	23	26	31	27	26	30	25	18	19
04	05	12	06	09	06	14	13	11	04	09	18	09	22	11	23	11	20	18	19	20	24	18	18
-01	-03	10	08	13	20	18	30	27	36	33	17	-00	21	22	16	34	31	33	45	40	41	46	43
06	-01	16	05	12	24	16	23	22	22	24	22	-00	16	13	22	38	31	38	38	38	40	39	41
07	02	12	08	15	21	15	23	18	23	18	26	03	21	17	17	26	24	25	29	31	28	28	33
07	-06	11	06	14	20	14	23	24	22	19	20	08	18	20	14	26	29	33	35	37	33	34	37
06	09	15	07	16	12	16	16	11	13	18	21	10	27	22	17	23	33	28	26	29	29	24	21
03	07	06	03	10	13	05	10	19	14	13	14	01	07	11	13	27	29	21	30	37	25	25	29
17	15	17	10	23	27	27	39	27	31	31	38	23	36	36	31	41	53	52	48	51	46	48	47
-05	01	05	-08	-08	02	-02	-01	02	03	04	07	-03	-14	-12	-03	-21	-07	-13	-10	-01	-12	-19	-08

RESULTS

Interpretation of the Factors

The interpretation of each of the 16 rotated factors is based upon the apparent factor content of the tests loaded significantly (.30 or higher) upon the factor. The test loadings for the factor in question are listed, along with any additional significant loadings of the tests, where they proved to be factorially complex. Each test name is preceded by its number in the battery and is followed by the trigram for its hypothesized factor. The classes factors are discussed first.

CFC - Cognition of figural classes

7.	Figure Classification (CFC)	.47	
5.	Figural Class Inclusion (CFC)	.46	
9.	Figure Exclusion (CFC)	.44	(.38 NFC)
6.	Figural Hierarchical Grouping (NFC)	.42	(.41 NFC)
10.	Multiple Figural Similarities (DFC)	.35	(.35 DFC)

The three leading tests on this factor had been hypothesized to define CFC. The third test, Figure Exclusion, however, is complex, having a loading of .38 on NFC. New consideration of this test suggests that its items are somewhat like partitioning tests for NFC, in which a list of items of information are to be segregated into mutually exclusive classes. In the exclusion type of test, E is actually to form two classes, one of them containing only one exemplar and the other containing three or four, as the case may be. From this point of view, the convergent-production variance in this and other exclusion tests is reasonable.

In the development of classes tests in the categories of divergent and convergent production, efforts were made to control cognition variance by utilizing common properties that are readily recognized. From the fact that Figural Hierarchical Grouping and Multiple Figural Similarities shared their variances with factor CFC, we see that those efforts were not entirely successful, for both of them share some cognition variance.

CSC - Cognition of symbolic classes

26.	Number Classification (CSC)	.53	
27.	Number-Group Naming (CSC)	.53	
13.	Letter Classification (CSC)	.43	
22.	Multiple Grouping of Nonsense Words (DSC)	.30	(.51 DSC)

Three of the four tests designed to measure CSC were loaded univocally on this factor. The fourth test, Letter-Group Exclusion, was loaded univocally on NSC instead. In this instance an exclusion type of test went entirely on the convergent-production factor corresponding to CSC, for which it was intended. Its loading on CSC was only .20.

The presence of the DSC test, Multiple Grouping of Nonsense Words, on factor CSC is another example of how a test designed for a production ability has some cognition variance creeping in, but in this case, the loading on the corresponding cognition factor is minimally significant.

CMC - Cognition of semantic classes

33. Sentence Classification (CMC)	.44	
11. Group Classification (NMC)	.41	(.43 NMC)
39. Word Classification (CMC)	.38	
37. Verbal Classification (CMC)	.35	(.36 NMC)
3. Classified Information (MMC)	.33	(.40 MMC)

The three tests designed to measure CMC were loaded significantly on this factor. Again we see a test designed to measure convergent production, Group Classification, with a substantial loading on a parallel cognition ability.

In the memory test, Classified Information, E is presented on the study page several sets of three words each, the words of a set sharing a common property. On the test page he is to recognize a new set of three words that have the same class property. Since E has to recognize the common attribute on both study page and test page, there are numerous opportunities for cognition variance to enter into the scores on this test.

It is of incidental interest that Sentence Classification had been originally selected as a potential measure of an evaluation ability (Hertzka, et al., 1954), under the name of Sentence Evaluation. It asks E to say whether each sentence is an example

Table 7

Factor Loadings for the Stage Scores in the Three Concept-Learning Tasks

	Trials	CFC	CSC	CMU	CMC	CMS	MSC	MMC	DFC	DSU	DSC	DMC	NFC	NSC	NMU	NMC	SEX	h^2
	1	10	-09	-10	09	-20	06	02	12	02	17	15	10	16	-22	10	-03	23
	2	-05	02	01	07	-14	10	05	04	14	10	09	07	17	-04	01	02	11
	3	14	00	-06	-02	-06	13	02	07	-03	14	11	20	09	-01	06	-01	13
	4	05	03	06	-08	03	17	20	-03	11	27	07	19	02	04	21	09	26
	5	26	01	-01	08	-02	23	25	07	01	11	05	11	-02	14	09	-01	25
Figural	6	12	-01	07	07	03	34	03	07	03	16	03	06	20	16	14	08	26
Task	7	24	10	04	08	-08	22	08	04	08	11	05	09	21	11	22	07	28
	8	13	23	03	10	09	24	11	-01	04	12	24	22	08	-06	17	13	34
	9	14	15	09	11	11	22	23	12	01	11	06	12	09	00	27	10	31
	10	12	13	10	23	09	27	18	07	16	13	14	18	09	05	22	15	39
	11	15	10	10	19	07	20	18	01	20	10	01	03	14	03	15	23	30
	12	21	10	14	20	08	07	19	08	13	19	02	21	16	03	03	08	30
	1	-10	-15	10	05	-06	-01	11	-06	11	08	-02	07	06	-03	07	-05	10
	2	03	-22	01	-07	-02	05	13	14	23	-01	-04	-04	06	-00	01	-11	16
	3	02	-06	12	-02	09	04	10	15	09	15	04	10	11	-10	03	00	13
	4	10	-03	06	-04	-01	10	08	09	-01	19	01	01	14	-06	01	-02	10
	5	08	-02	05	-07	07	10	14	03	11	20	01	02	24	04	11	-02	17
Symbolic	6	17	00	12	00	24	12	23	14	07	13	-02	01	13	01	03	-07	23
Task	7	15	03	03	-03	12	10	31	09	07	28	-05	-04	19	04	-03	-02	28
	8	18	15	15	-12	20	08	20	08	06	19	-00	-15	11	04	15	15	31
	9	13	03	06	08	24	10	10	03	-01	36	-06	05	17	07	08	02	28
	10	12	20	05	06	23	10	14	06	-05	26	-04	00	17	06	12	08	27
	11	13	15	02	05	20	12	26	15	00	24	-03	-01	06	10	08	00	27
	12	-02	17	06	-03	17	05	25	13	19	14	06	-04	15	06	06	14	25
	1	01	-03	04	-09	02	17	03	03	14	04	13	02	12	-15	02	02	12
	2	02	26	05	-06	03	21	16	10	14	17	21	07	18	-05	02	-04	29
	3	10	06	03	12	02	18	24	12	09	16	01	05	19	-07	11	-06	22
	4	05	10	11	-04	04	21	17	15	14	12	12	-09	18	06	-02	-04	21
	5	-03	14	13	16	05	11	20	06	04	18	07	10	15	13	21	-19	29
Semantic	6	09	10	10	04	03	13	30	17	14	19	03	-00	28	20	20	06	40
Task	7	19	09	26	-02	09	31	25	15	16	07	12	-13	13	-01	18	-08	42
	8	08	23	14	07	12	32	31	18	02	17	05	10	12	14	27	-04	48
	9	06	26	21	10	09	19	20	26	08	14	05	05	07	17	21	05	39
	10	05	25	19	15	-01	18	28	20	-01	17	17	11	11	05	23	-04	41
	11	12	20	17	13	01	23	31	12	-05	18	07	04	12	13	28	-08	42
	12	05	23	17	19	05	14	36	19	-07	13	10	16	04	04	32	-06	47

Note. — Decimal points omitted

Table 8

Means and Standard Deviations of the Concept-Verbalization Scores

	Concept	Mean	Standard Deviation
Figural Task	A. Intersecting lines	.67	.47
	B. Right angle lines	.59	.49
	C. Dotted lines	.92	.27
	D. Parallel lines	.45	.50
	Total	2.63	1.19
Symbolic Task	A. Double letter	.78	.42
	B. Letter s	.21	.41
	C. Begins with a vowel	.11	.31
	D. Alphabetical order	.59	.49
	Total	1.70	1.06
Semantic Task	A. Leader	.63	.48
	B. Part	.51	.50
	C. Animal sounds	.73	.45
	D. Food	.77	.42
	Total	2.65	1.37

of a statement of fact, of possibility, or is a matter of naming. With this description, it is apparent that the task is that of placing presented ideas somewhere in three defined classes. This kind of task turned out to be univocal for CMC in this test battery. There is still a possibility that Sentence Classification has some relation to the parallel factor EMC, for which there were no marker tests in the analyzed battery.

MSC - Memory for symbolic classes

17.	Memory for Nonsense Word Classes (MSC)	.82
18.	Memory for Word Classes (MSC)	.63

The two marker tests for MSC performed even better than was expected. Because of an unusual degree of visible similarity between these two tests, it may be that their loadings are somewhat inflated with a specific source of variance unique to the two.

MMC - Memory for semantic classes

28.	Picture Class Memory (MMC)	.40	
3.	Classified Information (MMC)	.40	(.33 CMC)

The two marker tests served their purpose in distinguishing this factor, but one of the tests showed some parallel cognition variance, as pointed out earlier.

DFC - Divergent production of figural classes

1.	Alternate Letter Groups (DFC)	.57	
21.	Multiple Grouping of Figures (DFC)	.40	
19.	Multiple Figural Similarities (DFC)	.35	(.35 CFC)

The three tests hypothesized to measure DFC were loaded on this factor. Multiple Figural Similarities, however, had a second loading of equal strength on CFC, indicating that the cognition aspect was not well controlled. Only tests designed for DFC appear significantly loaded on this factor.

Table 9

Correlations between Tests and the Concept-Verbalization Scores

Test	Symbolic Task	Figural Task	Semantic Task
1.	.32	.37	.30
2.	.22	.27	.38
3.	.25	.37	.48
4.	.24	.27	.40
5.	.38	.54	.55
6.	.37	.46	.47
7.	.34	.44	.40
8.	.39	.51	.51
9.	.34	.42	.43
10.	.24	.32	.43
11.	.21	.38	.41
12.	.33	.45	.49
13.	.47	.44	.52
14.	.37	.41	.48
15.	.37	.37	.40
16.	.39	.45	.45
17.	.25	.28	.36
18.	.34	.37	.43
19.	.23	.19	.15
20.	.12	.19	.23
21.	.40	.49	.50
22.	.37	.36	.36
23.	.34	.27	.30
24.	.27	.29	.32
25.	.19	.17	.20
26.	.39	.50	.49
27.	.32	.40	.46
28.	.22	.27	.37
29.	.34	.36	.40
30.	.42	.48	.42
31.	.37	.40	.43
32.	.21	.31	.31
33.	.32	.37	.50
34.	.39	.43	.46
35.	.23	.39	.28
36.	.20	.26	.28
37.	.41	.50	.54
38.	.27	.37	.48
39.	.30	.41	.48
40.	.35	.43	.54
41.	.28	.31	.37
42.	.27	.42	.45
43.	.34	.42	.53
44.	-.04	.12	-.09

Table 10

Factor Loadings for the Concept-Verbalization Scores

Learning Task	CFC	CSC	CMU	CMC	CMS	MSC	MMC	DFC	DSU	DSC	DMC	NFC	NSC	NMU	NMC	SEX	h^2
Figural Task	.20	.18	.05	.40	.20	.15	.09	.15	.13	.18	.13	.15	.14	.10	.19	.18	.52
Symbolic Task	.18	.23	.08	.18	.13	.12	.10	.12	.04	.32	.05	.08	.16	.10	.12	.08	.35
Semantic Task	.17	.28	.23	.41	.03	.17	.36	.08	.07	.13	.16	.19	.07	.13	.24	.04	.66

DSC - Divergent production of symbolic classes

22. Multiple Grouping of Nonsense Words (DSC)	.51	(.30 CSC)
24. Name Grouping (DSC)	.39	
23. Multiple Letter Similarities (DSC)	.37	

Three tests designed for DSC were found loaded significantly on it, with no tests designed for other factors. Multiple Grouping of Nonsense Words, however, had a minimally significant loading on CSC, the cognitive parallel.

DMC - Convergent production of semantic classes

36. Utility Test (DMC)	.73
20. Multiple Grouping (DMC)	.57
2. Alternate Uses (DMC)	.46

This factor has three univocal tests loaded on it, as expected, with the Utility Test, based upon the shift-score principle, clearly leading the three.

NFC - Convergent production of figural classes

8. Figure-Concept Grouping (NFC)	.50	
6. Figural Hierarchical Grouping (NFC)	.41	(.42 CFC)
9. Figure Exclusion (CFC)	.38	(.44 CFC)
10. Figure Grouping (NFC)	.32	

Three of the four tests designed for NFC performed primarily as expected, two of them being univocal for NFC. As pointed out in the discussion of CFC, Figural Hierarchical Grouping was not free from figural-cognition variance. The figures tended to be complex, with more attributes than usual in order to dete rmine the necessary hierarchical classification in each problem. This condition evidently generated some cognitive problems.

The test that failed, Restricted Figural Classification, differed from the rest, in that it called for two different partitionings of a set of six exemplars. Calling for more than one pair of groups might lead one to expect some DFC variance, but neither this factor nor any other in this analysis was loaded significantly on this test. There is no apparent hypothesis to suggest what factor outside this analysis might be strongly represented.

NSC - Convergent Production of symbolic classes

16. Letter Grouping (NSC)	.61
32. Restricted Symbolic Classification (NSC)	.47
15. Letter-Group Exclusion (CSC)	.41
14. Letter-Concept Grouping (NSC)	.30

Table 11

Factor Loadings for the Mastery Scores

Score	CFC	CSC	CMU	CMC	CMS	MSC	MMC	DFC	DSU	DSC	DMC	NFC	NSC	NMU	NMC	SEX
Figural Task																
A	.23	.14	.13	.13	.22	.20	.00	.05	.19	.12	.08	.15	.05	-.09	-.00	.10
B	.15	.19	.10	.10	.21	.20	.06	.09	.04	.09	.01	.07	.15	.07	.05	.26
C	.13	.08	-.12	-.03	-.03	.18	.19	.14	.03	.16	.07	.02	.10	.12	.06	-.03
D	.20	.29	.03	.13	.10	.27	.03	.01	.16	.01	.01	.14	.12	.02	.15	.12
Symbolic Task																
A	.01	.19	.03	-.04	.02	.07	.26	.00	.10	.13	-.04	-.01	.15	.06	.14	.20
B	-.10	.15	-.04	-.05	.05	.01	.08	.07	.12	.14	.15	.09	.10	-.08	.09	.19
C	.09	-.04	.13	-.17	.23	.12	.04	.10	.06	.13	.07	-.15	.12	.10	-.03	.10
D	.11	.12	.09	.05	.15	-.01	.22	.05	.15	.22	.08	-.04	.13	.13	.04	-.01
Semantic Task																
A	.11	.14	.26	.02	.06	.16	.16	.20	.06	.12	.04	-.05	.10	.04	.27	-.01
B	-.03	.18	.26	.23	-.04	.08	.13	.14	-.06	.16	.09	.11	.09	.09	.24	.03
C	.03	.10	.15	.05	.01	.21	.17	.04	-.04	.08	-.02	-.04	.16	.02	.33	-.06
D	.14	.12	.04	.11	.16	.07	.25	.18	-.07	.12	.06	.07	.04	.07	.29	.01

Three tests designed to measure NSC had significant loadings on that factor, plus the exclusion type of test designed for CSC, which failed to have much cognitive variance. The tests designed for NSC proved to be univocal for it, but one with only marginal variance.

NMC - Convergent production of semantic classes

11.	Group Classification (NMC)	.43	(.41 CMC)
43.	Word Grouping (NMC)	.42	
4.	Concept Grouping (NMC)	.37	(.49 CMU)
37.	Verbal Classification (CMC)	.36	(.35 CMC)
12.	Largest Class (NMC)	.34	

Two of the four tests for NMC were loaded univocally on NMC — Word Grouping and Largest Class. The former had played a key role in discovering the factor (Merrifield, et al., 1962); Largest Class was entirely new. The resemblance between this test and the exclusion types should be clear, the major difference being that the smaller class in an item in Largest Class is likely to have more than one exemplar left in it. Largest Class does not share any significant variance on the corresponding cognition factor, however, as some of the exclusion tests do.

Two other tests designed for NMC have significant loadings on it, but also substantial second loadings. Group Classification shares an equal amount of variance with CMC, undoubtedly because there is some difficulty in seeing the common attributes. The strong CMU loading for Concept Grouping suggests some difficulty with vocabulary level in that test or some need for precision of meanings. In order to control for cognition of semantic units in the semantic-classes tests, efforts were made to keep vocabulary level well within the range of ability of all high-school students. Although successful for the most part, these efforts appear to have failed in the case of Concept Grouping.

The loading of Verbal Classification on NMC came as a surprise, although this test has had a history of a relatively weak, significant loading on CMC. But when the nature of this test is reexamined, it has much resemblance to tests of the partitioning type constructed for NMC. In Verbal Classification E is to assign words of a list to one of two classes or to neither, the classes being defined by two given groups of words, the words of each group sharing a common property. This task could be considered as forming a unique classification of words in three exclusive classes. From this point of view the loading on NMC is reasonable.

The Non-class Factors

CMU - Cognition of semantic units

38.	Verbal Comprehension (CMU)	.68	
40.	Word Completion (CMU)	.62	
4.	Concept Grouping (NMC)	.49	(.37 NMC)

The striking thing about this list is the absence of all except one of the non-vocabulary, semantic tests, indicating generally good control of vocabulary level in the semantic tests other than those for CMU.

CMS - Cognition of semantic systems

10.	Problem Solving (CMS)	.60	
14.	Ship Destination (CMS)	.45	
44.	Sex	.38	(.49 SEX)

No classes tests had significant loadings on factor CMS, nor did any tests for other reference factors. CMS was the only ability factor on which the variable of Sex had a significant loading. The positive loading indicates a sex difference in which boys are superior to girls. The common name for this factor is "general reasoning," which has a history of being correlated with sex membership.

DSU - Divergent production of symbolic units

41.	Word Fluency (DSU)	.66
34.	Suffixes (DSU)	.62

No other tests, whether for classes or not, had significant relationships with DSU.

NMU - Convergent production of semantic units

29.	Picture Group Naming (NMU)	.51
42.	Word Group Naming (NMU)	.45
25.	Naming Meaningful Trends (NMU)	.40

The two leading tests, originally designed as classes tests, persisted here in going on factor NMU as previously, in spite of the unusually large number of classes tests in the battery. The naming act (finding the right word or verbal expression) definitely outweighed cognition of classes as a source of test-score variance. The same kind of result is true for the trends test, which had been designed originally for CMR, relations being involved instead of classes.

SEX

44.	Sex	.49	(.38 CMS)

As is somewhat common when the tested sample has members of both sexes involved, a Sex variable is analyzed with the test variables in order to take care of common sex differences. In this analysis there proved to be only trivial sex differences except for tests for factor CMS.

The Concept-Learning Experiment

This section examines the data pertaining to the relation of the learning-task scores to the common factors, the basis being found mainly in Tables 7, 10, and 11. An attempt will be made to extract as much generalizable information as possible from many arrays of numbers. A major interest concerns the relations of cognition, divergent- and convergent-production factors to the scores obtained from the learning tasks, for it was hypothesized that they should be among the most relevant for performance in those tasks.

In view of the attention paid to the three kinds of content, and the fact that abilities for dealing with those kinds of content are separate and distinct in factor analyses, there follows the prediction that factors CFC, DFC, and NFC should be relevant in connection with the figural-concept task; CSC, DSC, and NSC should be relevant in the symbolic task; and CMC, DMC, and NMC should be relevant in the semantic task. At least there should be some differential relations of task scores to factors, depending upon similarity of content involved in the task. There will be attention, however, to cases in which there seem to be crossovers in content, that is, the learning in one content category seems to be systematically related to some factor or factors in other content categories. There will be attention to factors, other than these nine, that stand out by having exceptionally higher loadings for certain tasks. And there will be some comparisons of the factor composition of the three different kinds of learning scores.

The Stage Scores

The Figural Tasks. The relations of the stage scores from the figural task to the three factors CFC, DFC, and NFC, as indicated by the factor loadings, are displayed in Fig. 2. In this kind of display, we can look for possible trends in loadings as functions of stage of practice. The points are plotted to represent the factor loadings as presented in Table 9, but the lines drawn to show the trends are based upon a process of smoothing by the method of moving averages applied iteratively. In the cases of DFC and NFC, the end results were so near to horizontal straight lines that two such lines were drawn at the levels of the means of factor loadings for the factors. It appears that there were no trends whatever for these two factors in relation to the figural stage scores, but the central tendencies of the factor loadings are on the positive side, in accordance with the positive correlations in Table 6. The points representing the 12 loadings may be regarded as deviations from each line. It should be remembered, of course, that means also fluctuate, and in replications of this study they might go as low as zero or lower.

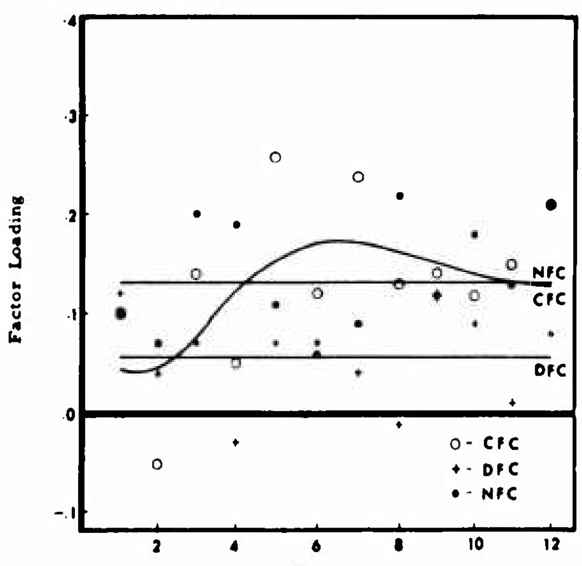

Fig. 2. Factor loadings for three classes factors as functions of stages in the figural-concept task, with smoothed trends.

From the smoothed trend of the data for CFC, it would appear that the influences of that factor for producing individual differences in stage scores is greatest near the middle of the whole learning event and possibly greater near the end of practice than at the beginning. One should expect loadings to be lower near the beginning of practice because scores at that place are less reliable and because S has not yet had enough exposure to different exemplars to be able to cognize the class concepts correctly. One might expect loadings to drop near the end of practice, especially if scores are all approaching the upper limit. Reference to Fig. 1 shows that the last-stage mean score for the figural task was, indeed, about 7.0, where the limit is 8.0, a condition that should have reduced variance of scores a great deal with a larger proportion of error variance at the expense of common-factor variance. In the middle of the learning event Ss should have accumulated enough experience with exemplars to let effects of factor CFC show. But CFC appears to the extent of only four per cent, if we may accept the data at face value.

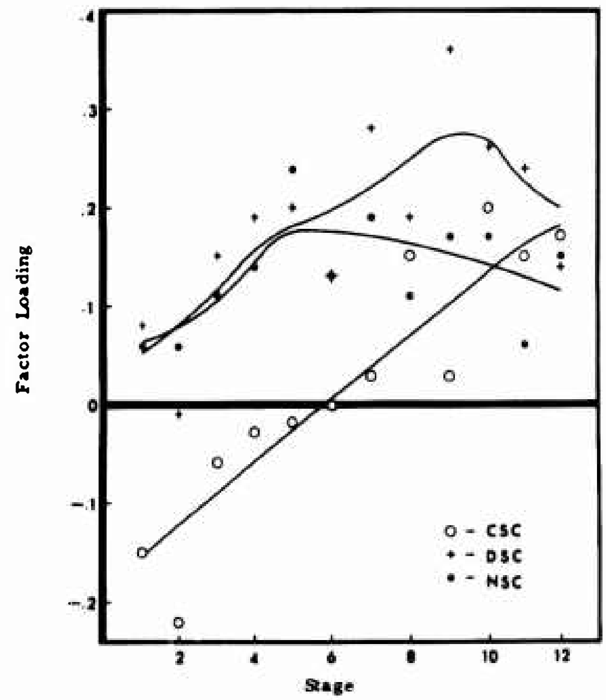

Fig. 3. Factor loadings for three classes factors as functions of stages in the symbolic-concept task, with smoothed trends.

The Symbolic Task. In Fig. 3 it will be seen that the trends seem more decisive and show greater vertical movement than for the figural task. Curiously, the effects of factor CSC appear to be negative during the first five stages. Negative loadings should mean that the factor makes reverse contributions to the scores and having a high status on CSC is a handicap rather than an asset. It is difficult to see how a relevant ability could operate in reverse. This finding should be followed up by special research. Beyond stage 6 in the task, loadings of CSC for the symbolic task keep increasing in a (smoothed) linear manner, but with wider fluctuations in loadings. In contrast to the relation of CFC to the figural task, there is no systematic decline in the last five trials. Reference to Fig. 1 shows that the means for the later stages in the symbolic task keep well below the upper limit of 8.0, thus leaving more room for common-factor variance.

Unlike the figural task, the symbolic task shows distinct trends for the regressions of loadings on the two production factors. The curve for DSC shows its maximal loadings late in the learning event and that for NSC shows its maximum relatively early. This is in reverse order to what one should expect. One should expect more effect of DSC earlier, when there is more trial-and-error behavior, when S is trying out different hypotheses about the concepts and rejecting most of them. After S has acquired the right conceptions, his task is more like that in tests of NSC, in which he partitions exemplars into already known classes. The difference between the concept-learning task of this type and tests of convergent-production factors for classes, however, is that in the former Ss have in view only one exemplar at a time and in the latter they have a whole list of exemplars. Fig. 3 suggests the positive roles of DSC and NSC, however, and that the extent of the contributions may go as high as about 12 per cent at trial 9 for DSC, or as high as about 9 per cent if we take the smoothed value. Both tend to diminish in weight when practice proceeds beyond maximal points.

The Semantic Task. For the relation of the classes factors to the stage scores in the semantic task, the same kind of display is given in Fig. 4. It is possible that the curves for CMC and NMC should be rectilinear, but in the smoothing process they persisted in converging to the trends shown. Even the curve for DMC might be a chance deviation from a horizontal straight line. But if the latter has genuine convexity upward, it is in direct opposition to the parallel function for DSC in the symbolic task, as shown in Fig. 3.

The curve for CMC as a function of stage of practice is in general much like that for CSC for the symbolic task, even to the short negative phase at the earliest stages. All three trends in Fig. 4 are generally on the upgrade to the very last stage. Although the learning curve for the semantic task does not come so close to the limit of 8.0 in the last trials as does the curve for the figural task, it is not so very far behind, up to the very last two stages. There seems little doubt of the generally increasing loadings of both CMC and NMC in this task and that their apparent contributions undergo systematic changes that may not be simple.

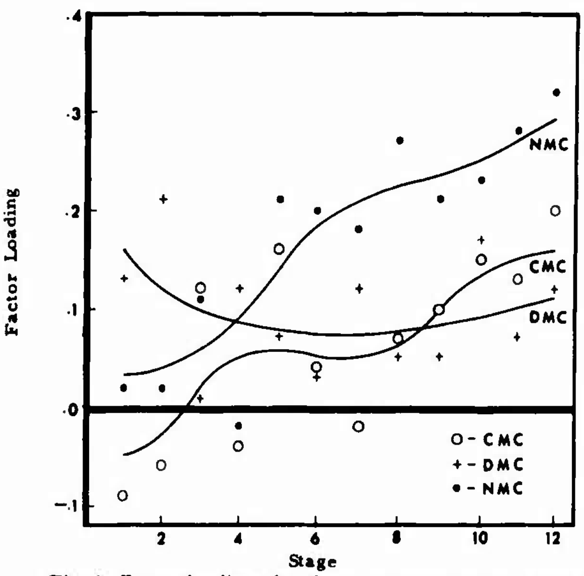

Fig. 4. Factor loadings for three classes factors as functions of stages in the semantic-concept task, with smoothed trends.

In order to obtain accelerations and decelerations such as those in Fig. 4, learners in the group must somehow, for some reason, synchronize their strategies of working on the task. In one kind of strategy, one or more factors should be more relevant and in some other strategy, one or more other factors. If the Ss each emphasized the various factors in a purely random sequence, we should expect such factors as show relationships at all to learning scores to have loadings that fluctuate around a constant level. This should be the case shown by factors DFC and NFC in Fig. 2. Systematic movement in either direction vertically, should be found wherever Ss tend to synchronize their changes of method, or kinds of operations.

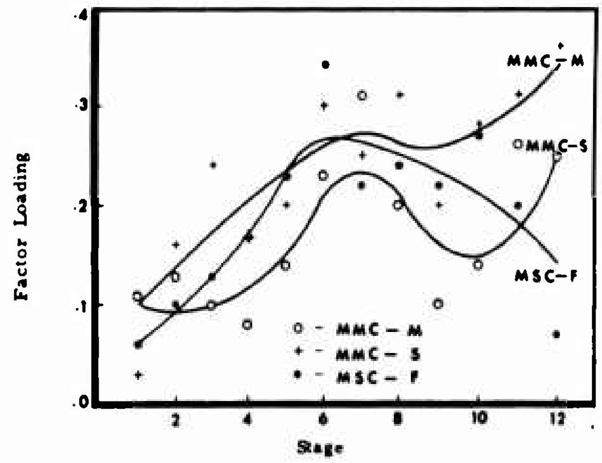

Fig. 5. Factor loadings in two memory factors as functions of stages in the three concept-learning tasks.

Relation to Memory Factors. One of the surprises in the results relating learning scores to the factors in this study was the relative prominence of loadings of the stage scores on the two memory factors involved in the analysis. Hindsight suggests how important it should have been to have included tests for MFC in the battery, but no such tests were in existence and were developed in another study much too late for use. The two memory abilities, MSC and MMC, showed some of the highest loadings of all, even for tasks other than symbolic and semantic, respectively. Fig. 5 shows three of the most relevant relationships; that of MSC with the figural task, and those of MMC with the symbolic and semantic tasks.

The most reasonable relationship is that between the semantic-memory ability, MMC, and scores from the semantic task. It is an almost continuously rising trend, with one possible short reversal past the middle of the learning event, ending at stage 12 with an indication of about ten percent of the variance attributable to that memory ability. All three curves rise from the beginning in much the same manner to an early peak at stages 6 to 7. They decline somewhat in synchronism to stage 9, but from that point part company, with the relation of factor MSC to the figural task ending at a level almost as low as its beginning.

Translations of Content. The crossing over of content, shown by the apparently significant relationships of MSC to the figural task and of MMC to the symbolic task, is not limited to three particular factors; it is more general, a fact that calls for comment.

In a real sense, the three content areas of information are three different "languages," each with its own coding. It is possible to feed into the organism's brain some information in one of these languages, but this is no assurance that the individual will process the information in the same language. He can and he apparently does some translating from one language to another, when free to do so, as indicated by factor loadings. Whether he translates or does not depends upon his adopted strategy. He may realize, consciously or unconsciously, that he is weak in one language and stronger in some other, in dealing with a particular kind of product, and he makes translations from the one to another to better his chances of success.

The translation into semantic form appeared to be the most common in this study, for factor MMC tended to have some of the strongest loadings. It had five loadings of .30 or greater, whereas MSC had three such loadings, with DSC and NMC having one each. This result is consistent with the common finding that the average person learns and remembers verbal (semantic) information most easily.

The translation can go in the opposite direction, as shown by the fact that the semantic task had two loadings (for two stage scores) of .31 on factor MSC. In tests each designed for a single factor, there is apparently less translation. This conclusion is evidenced by the fact that tests for two factors that differ only in content are relatively easy to separate in a factor analysis. In the simple task of a test, there is less opportunity for S to adopt strategies involving translations that may help him, often because of time limitations on the task and other experimental controls.

Table 12

Mean Factor Loadings and Numbers of Loadings of $\pm$ .20 or Greater for each Combination of Task and Factor for the Stage Scores

	Means of loadings			Numbers of larger loadings		
Factor	Figural	Symbolic	Semantic	Figural	Symbolic	Semantic
CFC	.13	.08	.07	3	0	0
CSC	.06	.02	.16	1	2*	6
CMC	.09	-.01	.06	2	0	0
MSC	.19	.08	.20	7	0	5
MMC	.13	.17	.23	3	5	9
DFC	.05	.09	.14	0	0	2
DSC	.14	.18	.14	1	5	0
DMC	.08	-.01	.09	1	0	1
NFC	.13	.00	.04	3	0	0
NSC	.12	.13	.14	2	1	1
NMC	.14	.06	.17	4	0	7
CMU	.04	.07	.11	0	0	2
CMS	.00	.12	.04	1*	5	0
DSU	.07	.07	.07	1	1	0
NMU	.02	.02	.05	1*	0	1

* In each case, one loading was negative.

A broader impression of the amount of translation that may be going on in the three tasks can be seen in the data of Table 12. In the first three columns of data are given the means of the factor loadings over all 12 stages, for each combination of factor and task. Each mean indicates the general level of relationship between factor and task, indicating the overall amount of positive contribution the factor may make to performance on each task. For this purpose the means are somehwat misleading, however, for they do not take into account the wide variations due to difference in trends. With reservations, then, we may compare the means in Table 12.

The chief item of interest at this point is whether the means are higher where factor and task represent the same kind of content. Except for the divergent-production factors, we see that the means do not fulfill expectations, although the means for the convergent-production abilities come close in this respect. The other three columns of Table 12 provide the same kind of comparisons, but based upon the numbers of higher ($\pm$.20 or stronger) factor loadings for the various combinations of factor and task. If one sets up a contingency table on the basis of agreements and disagreements between expected and obtained results of this kind in terms of content, the G index of agreement (Holley and Guilford, 1964) is .39; positive but small.

Roles of Non-Class Factors. The extension of the same kind of comparison to the four reference factors is of some interest, the data being shown in Table 12. Factor CMU had only two loadings of .20 or greater, in the semantic task where they should be expected, if anywhere. Although the words used in that task are generally familiar, this result may indicate that familiarity is not sufficient for all Ss.

The striking result in Table 12 is the report of five loadings for factor CMS in the symbolic task. Reference to Table 7 shows that these loadings came during the latter half of the learning event. The discrepancy between the S and M contents here suggests some translations from symbolic to semantic information. The fact that it is cognition of systems suggests that the Ss tended to verbalize the four-letter exemplars in terms of meaningful systems, in their attempts to find useful attributes. These are hypotheses that could be followed up by experiments.

The Verbalization Scores

The estimated factor loadings of the verbalization scores on the ability factors were presented in Table 10. If all Ss had mastered all four concepts in each task, the task requiring the naming of those concepts should be strongly loaded on factor NMU, which was included in this study to examine the extent NMU would possibly enter into the verbalization scores. From Table 10 we see that the three loadings on NMU were only .10, .10, and .13, in the figural, symbolic, and semantic tasks, respectively. The conclusion must be that NMU contributed very little to variances in the verbalization scores. The reason should be obvious. The learners were still quite varied in the extent to which they had mastered the concepts. If they had not mastered a concept they could not be expected to name or describe it. For a good test of NMU we should control the contribution of other factors by making sure that Es are aquainted with the concepts to be named.

The loadings in Table 10 should be expected to resemble most those for stage 12 of each task, as seen in Table 7. Except for the semantic task, the correspondence of rank orders of the corresponding loadings in Table 7 are very poor. All that can be said is that some of the highest loadings in the two tables are for the same combinations of factors and tasks. The more noteworthy exceptions of this generalization is that factor CMC shows up more strongly in Table 10, and the two memory factors somewhat more strongly in Table 7.

Comparisons of the communalities for the verbalization scores with those for the stage scores indicate that the 15 factors account for larger proportions of the variances of the former than of the latter. The 16-factor communalities for the three verbalization scores (based upon 15 aptitude factors and the one for sex membership, whose contribution was trivial) were estimated to be .52, .35, and .66, for the figural, symbolic, and semantic tasks, respectively. If we take the means of the last six communalities for each set of stage scores as estimates from that source, we find the values: .32, .28, and .43. Thus it would appear that the 15 common factors come nearer to accounting for variances in the verbalization scores than they do in the case of the stage scores.

The Mastery Scores

Reference to Table 11 will show that the factor loadings for the mastery scores tend to be a little lower than those for the other kinds of learning scores. One reason may be that they pertain to each concept separately whereas the other scores pertain to four concepts of a kind combined to give composite scores.

The higher loadings tend to be in places consistent with those for the other kinds of scores, except that the cognition factors do not seem to be so strong. The most decisive relationship comes for factor NMC in the semantic concept-learning task. This is not by any means matched by the corresponding factors NFC and NSC in relation to scores in those categories of content. There is no apparent effect of difficulty level of the concept upon factor loadings. Of the three kinds of scores, the mastery type thus gave the least information regarding relations of learning to factors.

DISCUSSION

The Abilities and Their Tests

The attempt to lend empirical support to the part of the SI model that is concerned with classes was quite successful. Eleven of the 20 classes abilities depicted by the SI model were investigated and identified by this study, two for the first time. It was also the first time that many of the others had appeared together in the same analysis; previous analyses have tended to keep within the same operation category, except for incidental inclusion of reference factors outside that category. With 36 tests employed to identify these 11 factors, 34 of them were found to have loadings consistent with their hypothesized content; only two were exceptions. The other, reference, factors were identified by their marker tests as expected.

Cognition Factors for Classes

The three previously established cognition-of-classes factors, CFC, CSC, and CMC, were again identified. Factor CBC had been demonstrated by O'Sullivan, et al., (1965). It was not under investigation in this study because no concept-learning task involving behavioral content was involved. Nine of the ten tests hypothesized to measure the three cognition-of-classes factors performed as expected. The exception, Letter-Group Exclusion, hypothesized for CSC, was loaded univocally on NSC instead. Two of the three CFC tests, three of the four CSC tests, and two of the three CMC tests were univocal for their respective factors. CFC and CSC were given additional support by the inclusion in the analysis of two newly developed tests. Figural Class Inclusion had a univocal loading on CFC; Letter Classification a univocal loading on CSC. Thus, seven of the tests designed for cognition of classes were univocal for their respective factors, and one additional test, Verbal Classification, did have a significant cognition loading but also a significant loading on NMC.

In the descriptions of tests in an earlier section, certain types of cognition-of-classes tests were pointed out—exclusion, inclusion, matching, and naming. It has already been pointed out in the preceding paragraph that the exclusion test for CSC, Letter-Group Exclusion, went entirely on the convergent-production factor NSC. The CFC exclusion test, Figure Exclusion, divided its variance between CFC and NFC, with the loading on the former a bit higher (.44 versus .38). The CMC exclusion test, Word Classification, was univocal on CMC, but was rather weakly loaded on it. On the whole, we can say that the exclusion type of test is not the best for cognition-of-classes abilities. It may be added that an exclusion test for CBC, Picture Exclusion, was univocally loaded on that factor (O'Sullivan, et al., 1965), but that analysis had no marker tests for the undemonstrated factor expected in the convergent-production category, factor NBC.

The three tests of the inclusion type were all univocal for their respective factors, with loadings of .46, .43, and .44 for Figural Class Inclusion, Letter Classification, and Sentence Classification, respectively. To this information we may add the fact that an inclusion test, Expression Grouping, designed for CBC was also quite successful, with a loading of .59 (O'Sullivan, et al., 1965).

Two matching tests, Figure Classification and Number Classification were relatively successful, with loadings of .47 and .53. The only naming test, Number-Group Naming, that succeeded, with a loading of .57, was for CSC. Two other class-naming tests, Picture-Group Naming and Word-Group Naming, however, were expected from previous experiences to go on factor NMU and they did so in this analysis. Number-Group Naming has gone on CSC before, so it seems to be a genuine exception among class-naming tests.

Memory Factors for Classes

Factors MSC and MMC were defined entirely by two tests each, as expected. Each factor had been demonstrated before, MSC by Tenopyr, et al., (1966) and MMC by Brown, et al., (1966). This analysis has confirmed their findings except for the fact that one of the MMC tests, Classified Information, had an additional significant loading on CMC. CMC had not been represented in the Brown analysis.

Divergent-Production (DP) Factors for Classes

The DP factors in this study were defined entirely by the nine tests designed for those abilities. Seven of these were found to be univocal, and none failed to have significant loadings on their appropriate DP factors. DFC and DSC had previously been adequately represented by only two tests each. The addition of the new tests, Multiple Grouping of Figures for DFC and Multiple Grouping of Nonsense Words for DSC, has buttressed the evidence for these two factors.

Of the five tests coming under the category of multiple grouping, four were univocal for their factors and the fifth just missed being univocal, with a loading of .30 in the cognition factor CSC. The loadings on their respective DP factors ranged from .39 to .57. The two tests classified under the description of "regrouping with a single exemplar outside the list" did rather poorly. These tests were Multiple Figural Similarities, for DFC and Multiple Letter Similarities for DSC. Their loadings were low and the DFC test had a second significant loading on CFC. The two tests under the principle of "shift" scores, Utility Test and Alternate Uses, were strong and univocal on DMC, as usual. A shift score would seem to be best for DP-of-classes abilities, with multiple-grouping scores not far behind, if we may generalize from this limited information.

Convergent-Production (CP) Factors for Classes

Ten of the 11 tests designed to measure CP of classes had significant loadings on their respective factors. Restricted Figural Classification, intended as a measure of NFC, had no significant loadings on any factors in this analysis. NFC and NSC had not been studied or identified previous to this analysis. NMC had been identified (Merrifield, et al., 1962) but by only one good test for it. The addition of the three new tests, Group Classification, Concept Grouping, and Largest Class, has substantially strengthened support for this factor. Two of the NMC tests, two for NFC, and three for NSC were univocal in this analysis.

Of the various categories of tests for CP abilities, those designated earlier as simple-partitioning tests seem to have the best record in this analysis. Figure Grouping, Letter Grouping, and Word Grouping had loadings of .32, .61, and .42, for their factors NFC, NSC, and NMC, respectively. Tests that require partitioning and the inclusion of an extra-list target exemplar did less well. Only one was univocal— Figure Concept Grouping, with a loading of .50 on NFC. The other two tests of this type had lower loadings on CP factors and secondary loadings on cognition factors.

The one CP test calling for a maximally uneven partitioning of lists (Largest Class) had a loading of only .34 on NMC and loadings on four other factors in the range .26 to .28; a very complex test. The two tests that called for partitioning six units by threes in two different ways achieved success in the one case and complete failure in the other. Restricted Symbolic Classification had a loading of .47 on NSC, but Restricted Figural Classification had a loading of only .19 on NFC, and no significant loading otherwise. The test Hierarchical Classification divided its variance about equally on CFC and NFC. A general conclusion that one might draw from all this experience with CP tests, especially, is that the tests that require simpler actions are more likely to be univocal and strong for their respective factors, a generalization that can often be made with respect to tests in other areas of ability.

Confusions of Contents and Operations

Although the solution of the factor problem was very clearcut in this investigation, there is some point in considering the few instances in which tests were of complexity two; none was of complexity three. As in other analyses of intellectual abilities, the separation of factors with respect to content was quite easy. In this study an unusually stringent test of the distinctness of the content categories was possible. Many of the classes factors employed had identical properties for the kind of content. None of these tests has a loading on a factor ordinarily defined by tests with different contents. In fact, the significant loadings in this analysis proved to be for factors in which the content was as expected.

Predicting the right kind of operations for a number of tests was another matter, however. The "misses" with respect to kind of operation were almost entirely in the nature of confusions between cognition and production abilities, more with respect to convergent production than divergent production. There were only two tests designed for DP abilities that had second loadings on corresponding cognition abilities and no cognition tests that had second loadings on DP abilities. But there were two CP tests with second loadings on corresponding cognition abilities and three cognition tests with significant loadings on CP abilities. There were enough other tests that were univocal on both cognition and production factors, however, to uphold the general hypothesis of orthogonality between the cognition and production categories of abilities.

Some difficulties with the full separation of tests of the other operation categories of memory and evaluation, as well as those of DP and CP, from cognition factors have been noted elsewhere. Gershon, et al., (1963) encountered this difficulty in connection with DP abilities; Nihira, et al., (1964) with respect to semantic-evaluation abilities; and Hoepfner et al., (1964) with respect to evaluation abilities. Such a systematic type of finding might suggest that cognition is a unique category of abilities; that cognition is basic to or is a necessary condition for the other kinds of functions. It is easy to see how such a principle could apply in connection with the production abilities, for if the individual does not have the necessary information at his command, he cannot produce certain effects that depend upon that information. Guilford and Hoepfner (1966) have assembled information showing that when a wide range of cognition ability exists in a group, the extent of cognitive ability appears to set upper limits upon DP abilities, but the lower limits are about the same for all levels of cognitive ability. The same kind of principle could apply to convergent production, although the feature of restrictions might modify the picture. Another general hypothesis, which could also be true, is that tests constructed for non-cognitive abilities have sometimes failed to rule out individual differences in cognition experimentally. As pointed out earlier, for the control of cognition variance, the cognitive aspect of the task must be so easy that no one would fail by virtue of being weak in cognition abilities. Another means of control would be to ensure by selection that all Es had a significantly high status on the relevant cognition ability.

Factors in the Concept-Learning Task

If the usual practice of regarding factor loadings of .30 or higher as being "significant" were followed, there would be little of a positive nature that could be said about the relation of factors to concept learning, in this investigation. An exception would be that four factors—MSC, MMC, DSC, and NMC—achieve that distinction in limited numbers of instances. But other circumstances call for serious consideration of the relevance of a number of the factors, possibly in addition to the four just named.

Relevance of Factors in Concept Learning

The correlations between the scores from the learning tasks and the factor-test scores are such as to be convincing that there is much in common between the two kinds of measures. Reference to Tables 6 and 9, where such correlations are presented, and to such correlations with the mastery scores, shows that those correlations are almost entirely positive, and that large numbers of them are statistically significantly different from zero, and that many of them are of substantial size, extending even into the .50's. Only by having factor variances in common could such correlations arise. This evidence comes directly from the basic data. It does not depend upon derived factor-analytic information.

Reflecting the correlations, however, the factor loadings that were estimated from them also give some assurance that those correlations are determined in part by factors that are in common to the tests. One bit of evidence is that the communalities estimated for the learning-score variables range as high as .48 for one of the stage scores and .66 for one of the verbalization scores. Another bit of evidence is that definite trends in factor loadings can be seen, as functions of stage of practice on the tasks. Trends, if genuine, imply system, and system means regularity, not randomness, in events.

Relevance of the Classes Factors. Of greatest interest, in connection with the question of relevance, was the performance of factors CFC, CSC, and CMC, since the learner can hardly escape the need for these abilities. The need did not show up as saliently as should be expected, however. All three factors did show trends in relation to the stage scores. Curiously, CSC and CMC showed signs of negative relations to the earliest stage scores, with rising trends dominating the picture, in relation to the symbolic and semantic tasks, respectively. But even the extremes of three functions showed no more than about 4 percent of the variance in the scores attributable to the factors.

It is well to remember that finding that there is a role for a factor in a task or test is a matter of pitching the level of difficulty such that there will be differential effects in the scores that are associated with individual differences in status on that factor. Finding non-chance evidence in the nature of a factor loading for a factor can be taken as evidence of a role for that factor. But finding no loading is not evidence of lack of a role for the factor. Presumably, consistent with the same principle, factor loadings can be gross underestimates of the degree to which a certain ability or function operates. Factor loadings should not be overestimates except by the intervention of chance. They can often be underestimates without the operation of chance.

The observable effect of divergent-production abilities were small and uncertain for the figural and semantic tasks. There were indications of contributions up to 9 percent of the variance in the symbolic task. The expectation that divergent-production abilities would be relatively more important early in practice and convergent-production abilities more important in later stages of practice was not born out, except that NMC came out strongly near the end of practice in the stage scores of the semantic task. But there was flatly contradictory indication in connection with the symbolic task. The influence of NFC appeared to be uniformly distributed over practice time for the figural task.

The two memory factors showed more consistently positive influence on task scores than did most factors, although there was no opportunity to verify this for the factor MFC. MMC showed relatively strong relations with the semantic task (up to about 10 percent), but also with the symbolic task. It is possible that some non-class memory factors would have added to the list of relevant factors, for units had to be remembered, also systems (in the case of the four-letter nonsense words in the symbolic task, for factor CMS showed some relation to that task). Memory for symbolic implications may also be involved in all the tasks, for S had to learn to associate each concept with one of four letters. Factor MSI might have shown relatively strong relations until late in practice, when such concepts as have been mastered have also been well-connected with their respective letters—A, B, C, or D.

From an important point of view, it is not surprising that memory abilities should be so well represented, relatively, in the learning of concepts, for there is much in common operationally between the tasks used in this study, or in other experiments on concept learning, and tests for memory factors. In the latter, too, there must be new learning and there is a test of status in the performance that is to indicate how much is retained, hoping that all examinees have had equivalent inputs from the study period. Which memory abilities will be more important in the experimental task will depend upon what contents and products are emphasized in the tasks and how well the task conditions standardize the strategies of the subjects.

Translations Between Content Categories

In the case of the two memory factors, especially, there were a number of instances of factors of one SI kind of content showing relations with tasks of a different SI content. The apparent involvement of MMC in the symbolic task was just mentioned. MSC was also apparently involved in the figural task, and CMS in the symbolic task. Such cross-overs were interpreted as instances of "translation" between different "languages." It would appear that the S often makes a choice as to which language he will favor. The fact that such translations can show up in terms of factor loadings means that many Ss agree on the choice of language other than that of the input information. In simpler tasks, such as tests designed for factors, such effects are apparently rare, the choice of language being better controlled by the test conditions.

Complexity of Learning Scores

The complexity of the tasks in this study as compared with univocal tests of factors should lead one to expect considerable factorial complexity in scores from those tasks. This is what was found, if one can accept some unusually small loadings as evidence for the involvement of the factors. The concept-learning tasks may be regarded as problems to be solved, with S being permitted to bring to bear upon them his various intellectual resources. It has been emphasized in a number of places before (e.g., Guilford, 1960) that a typical problem is usually a complex affair and naturally invites various intellectual functions into the picture.

The degree of factorial complexity of the concept-learning tasks is not by any means indicated by the loadings on several of the 15 factors represented in this study. It is quite apparent that the stage scores in any one of the tasks have much in common that is not accounted for by all 15 of the factors involved. When the three sets of stage scores, from intercorrelations of the 12 scores in each set, were factor analyzed within sets, the means of the communalities were .61, .64, and .60, for the figural, symbolic, and semantic tasks, respectively. The range of communalities over all tasks was from .37 to .76. These values came almost entirely from loadings in three common factors, where five factors had been rotated. The three corresponding means of communalities, which were averaged over all 12 stage scores (see Table 7,), were .26, .21, and .34.

The differences between corresponding pairs of communality values just given represent two general sources. One of these sources is from factors common to the learning scores only. In large part this source might be a specific factor, unique to each task, such as Fleishman has reported. Whatever its components, they are orthogonal to the 15 common factors shared by tests used in this study. The other source is from possible unknown factors, common to tests and learning scores but not brought out when the tests were analyzed alone. If we eliminated the contributions of the first source, the porportions of variance left for the stage scores should still be considerable. One could obtain an idea of the extent of the contributions from the second source by use of the residuals derived from the correlations between factors and stage scores. It was noted before that such correlations were much higher than one should expect from knowledge of the loadings of the 15 factors for the stage scores.

Similarity of the Kinds of Task Scores

It was mentioned in more than one place that the three kinds of task scores (stage, verbalization, and mastery) had similar patterns of factor loadings on the 15 common factors, with a few notable exceptions. This result should be reassuring to those who investigate concept-learning problems. But one should not generalize very far from this one experience of attempting to factor-analyze performance scores in such learning experiments. At this stage of knowledge, one cannot afford to take very much for granted. Note the failure of the prediction that the verbalization score should entail some variance in the naming factor NMU. Consistent with earlier discussion, in which it was pointed out that failure to find relevance of a certain factor does not necessarily mean that a naming operation is not involved, there could still be relevance for NMU, for naming is an obvious aspect of the test of risiduals of learning. Conditions relevant to the naming task may not have been such that individual differences in NMU have differential effects on the task scores. Or the relative contirbution of NMU might have been so trivial that it could not take more than about one percent of the total variance to its credit, as the three loadings near .10 suggest in Table 10.

Relations with Previous Studies

Satisfactory comparisons of results reported here with those cited from previous authors are hard to make. Although there is much similarity of the concept-learning tasks to those of earlier studies, the differences in test batteries were large. The main difference in this respect is that the previous investigators did not use tests designed to measure abilities involving classes. Unfortunately, tests involving classes have been very conspicuous by their absence in all traditional intelligence scales. In addition to different test batteries and different possibilities for finding comparable factors, there were even more important differences in rotation methods used. There was no systematic theory of intellectual abilities, applied either in the selection of tests or in rotations of axes to represent the factors.

There is little point, then, in attempting to find points of agreement or of contradiction. There is common agreement, between this study and a number of the others on certain general principles, one of which is that there are common factors represented among the learning-task scores that are not in common with the tests, and another of which is that there are factors in common to both tasks and tests. Whether there are factors common to test that are not in common to the task scores is more difficult to decide. There are probably such cases.

Different strategies for applying factor analysis to the general problem of factors in learning tasks have been utilized in the different studies. The strategy used in the current investigation, and in one or two others, has been to establish the reference frame for the factors by analyzing tests only, then fitting the task score into this reference frame by an extension of the correlation matrix and the factor matrix to include the task scores. For purposes such as pertained to the present study, this strategy seems to be fruitful.

Recommended Factor Tests

An additional goal, subordinate in this study to the demonstration of classes factors and to the analysis of learning scores into ability components, was to develop reliable and univocal tests for the classes factors under investigation. Those tests for which the analysis has revealed relatively high reliability and relative univocality of factor saturation can be recommended as tests to be employed in further research, and, possibly as candidates for use in applied areas.

On the basis of this and some past analyses, the tests considered to be the best measures of their respective factors are:

CFC	Figure Classification Figural Class Inclusion
CSC	Number Classification Number-Group Naming Letter Classification
CMC	Sentence Classification
DFC	Alternate Letter Groups Multiple Grouping of Figures
DSC	Multiple Grouping of Nonsense Words Name Grouping
DMC	Utility Test Multiple Grouping Alternate Uses
NFC	Figure-Concept Grouping
NSC	Letter Grouping Restricted Symbolic Classification
NMC	Word Grouping

SUMMARY

Although intellectual abilities have been measured for decades, their relevance to the processes of concept learning has been largely ignored. The significance of intellectual abilities has recently been emphasized by a theory of intelligence in which an entire domain of abilities concerning concepts is postulated. The present study attempted to provide further empirical foundation for these abilities and to investigate their relationships to performance on various concept-learning tasks.

Forty-three intellectual-aptitude tests were employed to measure 15 abilities postulated by the structure-of-intellect theory. Of the 15, 11 pertained to classes and 4 were reference factors involving units and systems. A factor analysis of these tests, based on scores of 177 high-school students, identified all of the hypothesized factors. The classes factors separated with regard to the type of content: figural, symbolic, and semantic; and with respect to the operation: cognition, memory, divergent production, and convergent production.

Three concept-learning tasks, utilizing the same three types of content as the tests, were also administered. Vectors representing the number of correct responses for each learning stage, the number of correctly verbalized concepts at the completion of practice on each task, and a mastery score for each concept were extended into the space of the aptitude factors. The results indicate that particular abilities are relevant to certain learning tasks at different stages of practice.

This investigation clearly indicates that any comprehensive theory of concept learning should take into account functions indicated by intellectual aptitudes. The structure-of-intellect theory provides a rich and useful source of hypotheses concerning such aptitudes.

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APPENDIX A

DESCRIPTION OF TESTS

1. Alternate Letter Groups - DFC03B.[1] Find letters of the alphabet that belong to a class because of a communality of shape or form.

Sample: Given **A H V T C**

Possible groups:

(a) AHVT (all letters made of straight lines)
(b) AHT (all letters have horizontal lines)

Score: Number of acceptable responses.
Parts: 2; items per part: 2; working time: 6 minutes.

2. Alternate Uses - DMC03C (SSC). List as many as six uses for an object, other than the common use which is stated.

Sample: Given: A NEWSPAPER. (used for reading). Uses: start a fire
wrap garbage
swat flies

Score: Number of possible, different uses listed.
Parts: 2; items per part: 3; working time: 8 minutes.

3. Classified Information - MMC01A. Recognize classes of words similar to those given on a previously studied page.

Sample study item:		Sample test items.			
	SILK		RAYON	SNOW	
	WOOL		COTTON	ICE	
	NYLON		FELT	SLEET	Answers: Yes, No.

Score: Number of correct responses minus the number of wrong responses.
Parts: 2; items per study page: 15; items per test page: 30; working time: 6 minutes.

4. Concept Grouping - NMC02A. Given a target word and a list of words, classify the words into classes so that the attribute of each class so formed is also an attribute of the target word.

Sample: 1. tar 4. log 7. gasoline
2. silver 5. ink 8. gold
3. raven 6. copper 9. kerosene

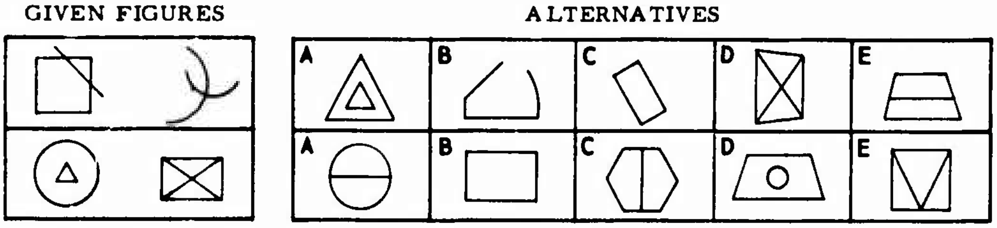
COAL
Class I: 1, 3, 5
Class II: 4, 7, 9
Class III: 2, 6, 8

Score: Number of correct classes.
Parts: 2; items per part: 3; working time: 6 minutes.

5. Figural Class Inclusion - CFC04A. Given two figures that have a common figural property, select from five alternatives the one figure that contains the same property.

GIVEN FIGURES ALTERNATIVES

Sample: 1. 2.



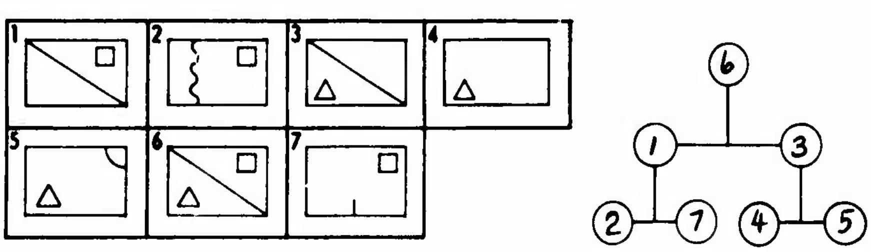
Answers: 1, D; 2, E.

Score: Number of correct responses minus one-fourth the number of wrong responses.

Parts: 2; items per part: 12; working time: 8 minutes.

6. Figural Hierarchical Grouping - NFC02A. Place figures into a hierarchical system based upon common properties.

Sample:



Score: Number of correctly classified figures.
Parts: 2; items per part: 2; working time: 10 minutes.

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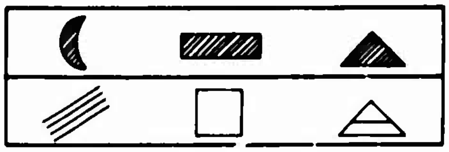
[1] The code immediately following each test name indicates the hypothesized factor content of the test at the stage of test construction. Additional codes are as follows: SSC - copyright by Sheridan Supply Co., Beverly Hills, California, adapted with permission; LLT - adapted with permission from a test by L. L. Thurstone; UNC - adapted with permission from a test developed at the University of North Carolina.

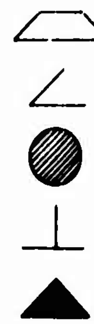
7. Figure Classification - CFC01A. Recognize classes of figures, then assign given figures to the classes.

Sample items:



ALTERNATIVES

A.
B.
C.
D.
E.

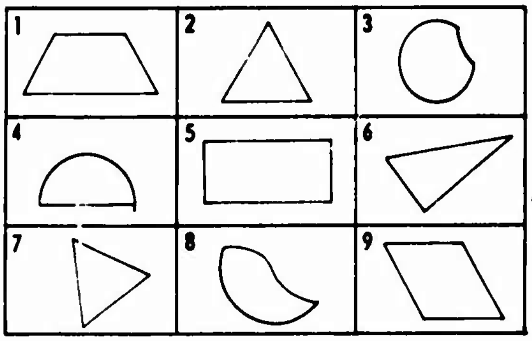


Answers: 1, C; 2, A.

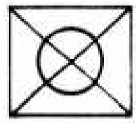
Score: Number of correct responses minus one-fourth the number of incorrect responses.
Parts: 2; items per part: 10; working time: 8 minutes.

8. Figure-Concept Grouping - NFC03A. Given a target figure and a group of figures, classify the figures into classes so that the attribute of each class formed is also an attribute of the target figure.

Sample:



TARGET

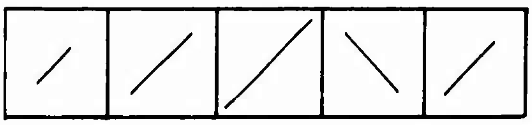


Class I: 1, 5, 9
Class II: 2, 6, 7
Class III: 3, 4, 8

Score: Number of correct classes.
Parts: 2; items per part: 3; working time: 8 minutes.

9. Figure Exclusion - CFC03A. Given five figures, show that you see what four have in common by excluding the one which is different.

Sample:



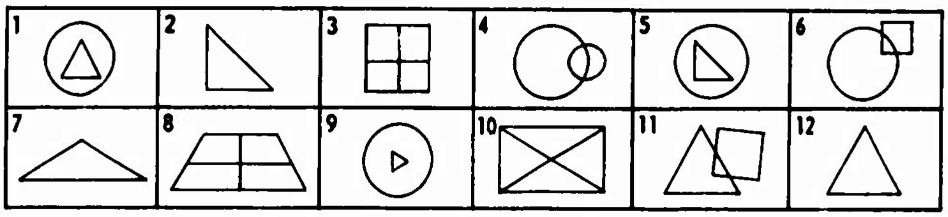
A B C D E

Answer: D.

Score: Number of correct responses minus one-fourth the number of wrong responses.
Parts: 2; items per part: 14; working time: 9 minutes.

10. Figure Grouping - NFC01A. Given a set of twelve figures, group the figures into four distinct classes using each figure once.

Sample:



Class I: 1, 5, 9
Class II: 2, 7, 12
Class III: 3, 8, 10
Class IV: 4, 6, 11

Score: Number of figures correctly classified.
Parts: 2; items per part: 3; working time: 8 minutes.

11. Group Classification - NMC03A. Given two target groups of words, classify additional groups of words in such a manner that each target group belongs to one of the classes.

Sample:

TARGET A

bargain	applaud
store	water

Class A 2, 4, 5, 8

TARGET B

ruler	bite
dog	thimble

Class B 1, 3, 6, 7

1

radio	sextant
ocean	fear

2

cloth	consent
tear	ice

3

scale	plastic
cheap	record

4

knife	captain
agree	cut

5

sugar	scratch
like	cat

6

hate	tool
bumper	clock

7

cook	sew
gauge	button

8

savings	can
approve	bank

Score: Number of correctly classified word groups.
Parts: 2; items per part: 2; working time: 10 minutes.

12. Largest Class - NMC04A. Given a list of words, form the largest possible class of words with the remaining words also making a class.

Sample:

1. button	4. zipper	7. mailbox
2. staple	5. filing cabinet	8. scotch tape
3. purse	6. paperclip	9. pocket

LARGEST CLASS: 1, 2, 4, 6, 8

Score: Number of correct classes.
Parts: 2; items per part: 4; working time: 8 minutes.

13. Letter Classification - CSC06A. Recognize classes of nonsense words, then assign given nonsense words to the classes.

Sample:

Items

1. ALF	OSTE	IBMR	
2. CFCO	AQOQ	HCHY	

Alternatives

A. LSUG
B. WAWO
C. DXTE
D. OFMA
E. ZSU

Answers: 1, D; 2, B.
Score: Number of correct responses minus one-fourth the number of wrong responses.
Parts: 2; items per part: 10; working time: 8 minutes.

14. Letter-Concept Grouping - NSC02A. Given a list of nonsense words and a target nonsense word, classify the words into classes so that the attribute of each class so formed is also an attribute of the target word.

Sample:

1. AMK
2. SBN
3. TFT
4. QIP
5. BYS
6. GHH
7. RDB
8. LLS
9. CVO

TBLET

Class I: 1, 4, 9
Class II: 3, 6, 8
Class III: 2, 5, 7

Score: Number of correct classes.
Parts: 2; items per part: 3; working time: 8 minutes.

15. Letter-Group Exclusion - CSC01B (LLT). Choose the group of letters that is different from the other three groups.

Sample:

(1)	(2)
A A B C	A C A D
(3)	**(4)**
A C S H	A A C G

Answer: 3.

Score: Number of correct responses minus one-third the number of incorrect responses.
Parts: 2; items per part: 20; working time: 8 minutes.

16. Letter Grouping - NSC01A. Given a list of nonsense words, group them into four classes using each word only once.

Sample:

1. LXD	7. OPQ
2. GOG	8. EEB
3. LZQ	9. RIR
4. BCD	10. LWP
5. MAA	11. KII
6. SUS	12. RST

Class I: 1, 3, 10
Class II: 2, 6, 9
Class III: 4, 7, 12
Class IV: 5, 8, 11

Score: Number of correctly classified nonsense words.
Parts: 2; items per part: 3; working time: 9 minutes.

17. Memory for Nonsense Word Classes - MSC02B. Indicate which of four nonsense words given in each item on a test page represents a class given on a previous study page.

Sample Study Items:

NEC	GUZ
NEP	GAZ
NEF	GYZ

Sample Test Items:

1. 1) GIS 2) GOZ 3) LOZ 4) MOZ
2. 1) NOP 2) NAR 3) NER 4) NUP

Answers: 1, 2; 2, 3.

Score: Number of correct responses minus one-third the number of wrong responses.
Parts: 1; items per study page: 10; items per test page: 10; working time: 4 1/2 minutes.

18. Memory for Word Classes - MSC04A. Indicate whether or not each of a number of words presented on a test page represents a class given on a previous study page.

Sample Study Items:

pan	test
ran	pest
fan	lest

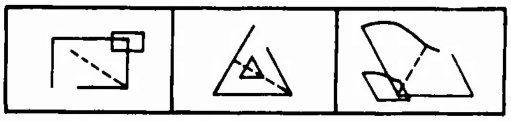
Sample Test Items: 1. west 2. boat 3. can

Answers: 1, Yes; 2, No; 3, Yes.

Score: Number of correct responses minus number of wrong responses.
Parts: 2; items per study page: 10; items per test page: 20; working time: 9 minutes.

19. Multiple Figural Similarities - DFC07A. Given a set of three figural objects that can be conceived as representing different classes, select single figures that can be classified with the set, each for a different reason.

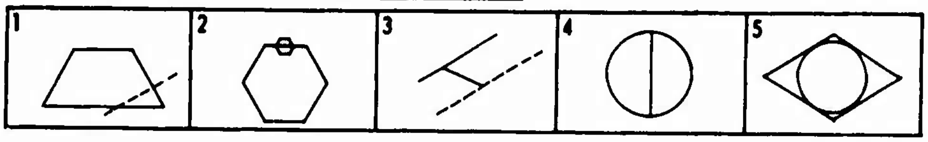
Sample: GIVEN CLASS



This class is like:

3, 1, 3, 2

ALTERNATIVES



Score: Number of correctly chosen alternatives. Parts: 2; items per part: 3; working time: 8 minutes.

20. Multiple Grouping - DMC02C. Arrange given words into several different meaningful groups.

Sample:

1. arrow
2. bee
3. crocodile
4. fish
5. kite
6. sailboat
7. sparrow

Class A: 1, 2, 5, 7

Class B: 3, 4, 6

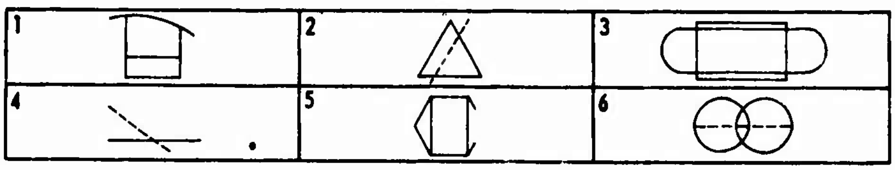
Class C: 2, 3, 4, 7

Class D. 3, 4, 5, 7

Score: Number of acceptable classes. Parts; 2; items per part: 1; working time: 4 minutes.

21. Multiple Grouping of Figures - DFC08A. Given a number of figures, group and regroup them into as many different classes as possible.

Sample:



CLASSES

1, 3, 6

1, 2, 3, 5

1, 3, 5

Score: Number of acceptable different classes. Parts: 2; items per part: 1; working time: 8 minutes.

22. Multiple Grouping of Nonsense Words - DSC05A. Given a list of nonsense words, form as many different classes as possible.

Sample:

Nonsense Word List

1. RUATWS
2. FJOSUX
3. EJLORU
4. AAKNPB
5. BOOQIC
6. HIOSTV

Classes

1, 4, 5, 6

1, 4, 5

2, 3, 6

2, 3, 5

Score: Number of correct classes. Parts: 2; items per part: 1; working time: 8 minutes.

23. Multiple Letter Similarities - DSC04A. Given a set of three groups of letters that can be conceived as representing different classes, specify alternative groups of letters that can be classified with the set for different reasons.

Sample:

Given Class

UPOH OKID IFEC

Alternatives

1. FOQI
2. ZHEM
3. IAO
4. MKICA
5. EIMCK
6. IJUME
7. NWRO
8. GOINU

This class is like Alternatives:

5, 4, 6

Score: Number of correctly chosen alternatives. Parts: 2; items per part: 4; working time: 8 minutes.

24. Name Grouping - DSC02B. Classify a group of common names into several groups based upon the different alphabetic properties they have in common.

Sample:

1. GERTRUDE
2. BILL
3. ALEX
4. CARRIE
5. BELLE
6. DON

Classes

1, 3, 4

2, 4, 5

1, 4, 5

1, 3, 4, 5

Score: Number of acceptable classes. Parts: 2; items per part: 1; working time: 6 minutes.

25. **Naming Meaningful Trends** - NMU04A (UNC). Recognize and express a trend in a group of words.

Sample: mouse rat lion pig cow horse elephant

animals become larger

Score: Number of correctly specified trends.
Parts: 1; items: 10; working time: 3 minutes.

26. **Number Classification** - CSC03C. Recognize classes of three numbers, then assign given numbers to the classes.

Sample:

1. 44 55 33
2. 10 45 15

Alternatives
A. 421
B. 53
C. 219
D. 22
E. 25

Answers: 1, D; 2, E.

Score: Number of items right minus one-fourth of the number wrong.
Parts: 2; items per part: 10; working time: 6 minutes.

27. **Number-Group Naming** - CSC05B. State what it is that three given numbers have in common.

Samples:

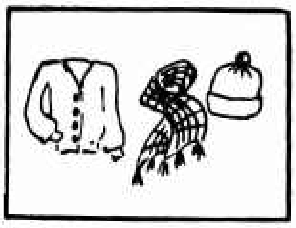
35 110 75 divisible by 5

676 65 161 ________

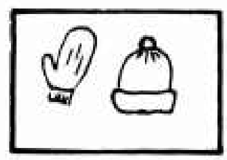
Score: Number of correctly named groups.
Parts: 1; items: 12; working time: 3 minutes.

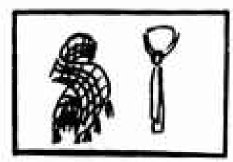
28. **Picture Class Memory** - MMC03B. Indicate whether or not a given two-element class represents the same concept as one given on a previously studied page.

Sample Study Item:



Sample Test Items



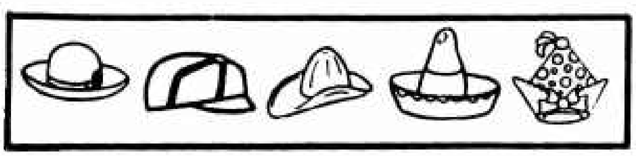


Answers: Yes, No.

Score: Number of correct responses minus the number of wrong responses.
Parts: 1; items per study page: 11; items per test page: 22; working time: 3 minutes.

29. **Picture-Group Naming** - NMU03A (UNC). Provide a class name for a group of five pictures.

Sample:



hats

Score: Number of correct names.
Parts: 1; items: 9; working time: 2 minutes.

30. **Problem Solving** - CMS05A. Solve verbally stated arithmetic problems where the numerical calculations are minimized.

Sample: A ship can cruise from L to S before its fuel supply is exhausted. To what point could it cruise and return with the same amount of fuel?

L M N O P Q R S

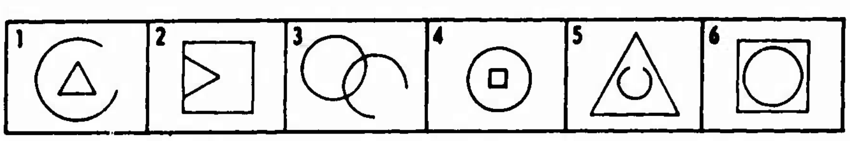
A. Between N and O
B. To exactly O
C. Between O and P
D. To exactly P
E. Between P and Q

Answer: C.

Score: Number of correct responses minus one-fourth the number of wrong responses.
Parts: 1; items: 10; working time: 10 minutes.

31. **Restricted Figural Classifications** - NFC04A. Classify a given set of figures so that each figure is a member of two classes.

Sample:



Class I: 1, 3, 5
Class II: 2, 4, 6
Class III: 3, 4, 6
Class IV: 1, 2, 5

Score: Number of figures correctly classified twice. Parts: 2; items per part: 4; working time: 8 minutes.

32. **Restricted Symbolic Classifications** - NSC04A. Classify a given list of nonsense words so that each word is a member of two classes.

Sample:

1. AVFB
2. SCPZ
3. MWDN
4. POYT
5. GXKH
6. WPIR

Class I: 1, 4, 6
Class II: 1, 3, 5
Class III: 2, 3, 5
Class IV: 2, 4, 6

Score: Number of nonsense words correctly classified twice.
Parts: 2; items per part: 3; working time: 8 minutes.

33. Sentence Classification - CMC03A. Designate sentences of two short paragraphs as conveying either (A) fact, (B) possibility, or (C) name.

Sample:

1. The natives of New Zealand have woode' houses which meet the requirements for cool climate.
2. The Rarotongan word vari means "mud."
3. The gods informed the people of Tahiti of the disaster.

Answers: 1, A; 2, C; 3, B.

Score: Number of correct responses minus one-half the number of wrong responses.
Parts: 2; items per part: 15; working time: 8 minutes.

34. Ship Destination Test - CMS02D (SSC). Find the distance from a ship to a port, taking into account the influence of an increasing number of variables.

Score: Number of correct responses minus one-fourth the number of wrong responses.
Parts: 1; items: 24; working time: 8 minutes.

35. Suffixes - DSU01A (LLT). Write words ending with a specified suffix, such as able.

Score: Number of correctly listed words.
Parts: 1; items: 1; working time: 3 minutes.

36. Utility Test - DMC01A. List as many uses as possible for a common object.

Score: Number of shifts in category in a series of acceptable responses.
Parts: 2; items per part: 1; working time: 10 minutes.

37. Verbal Classification - CMC02B (LLT). Assign words to one of two classes, or to neither, each class being represented by a set of four words.

Sample:

COW		desk	✓	TABLE
HORSE	✓	sheep		CHAIR
GOAT		rocker	✓	BOOKCASE
DOG		tree		LAMP
	✓	cat		
		nose		
		dresser	✓	
	✓	donkey		

Score: Number of correct responses.
Parts: 2; items per part: 5; working time: 8 minutes.

38. Verbal Comprehension - CMU02C (SSC). Select from a group, a word that means about the same as a given word.

Sample: EARTH A. sugar B. farm C. sun D. soil E. horse Answer: D.

Score: Number of correct responses minus one-fourth of the number wrong.
Parts: 1; items: 24; working time: 4 minutes.

39. Word Classification - CMC01B. Select the one word in a set of four that does not belong to the class on the basis of meaning.

Sample: A. horse B. cow C. man D. flower Answer: D.

Score: Number of items right minus one-third of the number wrong.
Parts: 1; items: 20; working time: 5 minutes.

40. Word Completion - CMU01B. Write acceptable meanings for given words.

Sample:
COURAGEOUS to be brave

Score: Number of acceptable definitions written.
Parts: 1; items: 20; working time: 5 1/2 minutes.

41. Word Fluency - DSU02A (SSC). Write words containing one specified letter, such as O.

Score: Number of different words written containing the specified letter.
Parts: 2; items per part: 1; working time: 4 minutes.

42. Word-Group Naming - NMU02A. Give a class name to a group of five words.

Sample: knife pan bowl rolling pin strainer
cooking utensils

Score: Number of correct names.
Parts: 1; items: 16; working time: 6 minutes.

43. Word Grouping - NMC01B. Given twelve common words, put them into four, and only four, classes, leaving no extra words.

Sample:

1. blue	5. larger	9. opener
2. cutter	6. light	10. orange
3. driver	7. little	11. redder
4. heavy	8. long	12. short

Class I: 1, 10, 11
Class II: 5, 7, 8, 12
Class III: 4, 6
Class IV: 2, 3, 9

Score: Number of words correctly classified.
Parts: 2; items per part: 2; working time: 6 minutes.

APPENDIX B
INSTRUCTIONS AND SAMPLE PAGES FROM THE LEARNING TASKS

The instructions below are those used to introduce the figural learning task (Problem 200). There were, however, two additional problems, one with nonsense syllables for the symbolic task (Problem 100), and one with groups of four words each, for the semantic task (Problem 300). For each type of task a separate instruction sheet was furnished. For this Appendix, only the figural instructions are provided; but the reader could insert the words "nonsense words" or "groups of four words each" for the term "figure" to make these instructions compatible for all three concept-learning tasks.

Instructions for problem 200

In this problem you will be presented with 96 different figures. These figures form four distinct classes represented by the capital letters A, B, C, and D. All of the figures associated with a particular letter have something in common. There are 24 figures associated with the capital letter A, 24 with B, 24 with C, and 24 with D.

Your task is to learn to assign the correct letter to the figures, by figuring out what common property is associated with each letter. For example, figures with curved lines might be associated with A, and figures with three parts might be associated with B. The classes are distinct; that is, no figure will be associated with more than one letter. The classes you are to identify in the problem are different from those just mentioned.

On the first page of the problem booklet you will be presented with a figure followed by the letters A, B, C, and D. Choose or guess the letter you think is associated with this particular figure. After you have circled your choice, turn the page and the figure will be presented again, but followed this time by the correct letter. On the same page a new figure will be presented, and again you are to choose A, B, C, or D. The next page will have the letter correctly associated with this figure.

This process will be repeated until all 96 figures have been presented. During the first few trials you probably will have to rely on guessing. However, on later trials you should be able to make accurate predictions since all of the figures associated with a particular letter have something in common.

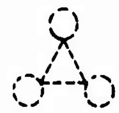
You will be instructed when to turn each page, when to examine the answer, and when to look at the new figure. It is very important that you follow these instructions.

Do not leave any page blank. Always circle one of the four letters. If you do not know the correct answer, make your best guess.

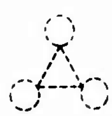
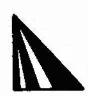
Sample problem booklet

ANSWER ALL ITEMS IN THIS BOOKLET. IF YOU HAVE NO IDEA OF THE CORRECT ANSWER - GUESS. YOUR GUESSES ARE IMPORTANT FOR THE ANALYSIS OF THESE PROBLEMS.

Sample first page

PROBLEM 100	101	LLAM	A B C D
PROBLEM 200	201		A B C D
PROBLEM 300	301	fence quiet sour director	A B C D

Sample second page

		Answer			
101	LLAM	A	102	SOZF	A B C D
201		Answer C	202		A B C D
301	fence quiet sour director	Answer A	302	part extreme repeat garden	A B C D

Verbalization measures

At the conclusion of 96 trials of any one problem, S was presented with the folowing page, on which he was to verbalize, by writing, the basis upon which he made his class assignments.

Describe the common property associated with each letter.

Problem 100	A	______
	B	______
	C	______
	D	______
Problem 200	A	______
	B	______
	C	______
	D	______
Problem 300	A	______
	B	______
	C	______
	D	______

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13. ABSTRACT

The present study attempted to provide empirical foundations for the classes abilities and to investigate their relationships to performance on various concept-learning tasks. (U)

A factor analysis of 43 intellectual-aptitude tests, based upon 177 high-school students, identified 15 abilities hypothesized by the structure-of-intellect theory. Of the 15 factors, 11 pertained to classes, and these classes factors separated with regard to the type of content: figural, symbolic, and semantic; with respect to the operation: cognition, memory, divergent production, and convergent production. (U)

Three concept-learning tasks, utilizing the same three types of content as the tests, were also administered. Vectors representing the number of correct responses for each learning stage, the number of correctly verbalized concepts at the completion of practice on each task, and a mastery score for each concept were extended into the space of the aptitude factors. The results indicate that particular abilities are relevant to certain learning tasks at different stages of practice. (U)

This investigation clearly indicates that any comprehensive theory of concept learning should take into account functions indicated by the intellectual aptitudes. The structure-of-intellect theory provides a rich and useful source of hypotheses concerning such aptitudes. (U)

14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Classes						
Concept Learning						
Factor Analysis						
Intelligence						
Tests						

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